THE SCIENCE MASTERS' BOOK

SERIES I

PART II

CHEMISTRY—BIOLOGY—CONVERSAZIONE EXPERIMENTS

THE SCIENCE MASTERS' BOOK

Series I

PART I. PHYSICS

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SCIENCE MASTERS' BOOK

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PART II

CHEMISTRY—BIOLOGY—
CONVERSAZIONE EXPERIMENTS

BEING EXPERIMENTS SELECTED FROM THE *SCHOOL SCIENCE REVIEW* BY A COMMITTEE OF THE SCIENCE MASTERS' ASSOCIATION

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PREFACE

SINCE the *School Science Review* was started in June 1919, notes on Apparatus and Experiments have been a fairly constant feature, and this book is the natural outcome. Besides contributions from members of the Science Masters' Association, many have been obtained, directly or indirectly, from University teachers—directly, in the form of articles and notes to the *School Science Review*; indirectly, in the form of demonstrations given at the Annual Meetings of the Association.

A great many of the notes are original, or believed to be original, though it is sometimes difficult, particularly in Natural Science, to be quite certain on that point. Many, however, whose names are put to the notes, emphatically disclaim original authorship. The ideas have been acquired from forgotten sources, and no doubt many old ways of doing things have been here brought up again.

The book is necessarily a scrap book, and it is inevitable that it must lack continuity. Another peculiarity incidental to this kind of compilation is the somewhat rapid transition, even within a single section, from work suitable for the Middle School to that of the Sixth Form and the Scholarship candidates.

Scraps are not easy to arrange in such a way as to gain general approbation. Some expect to find all country churches together and all country inns; others prefer that they should appear topographically. A desirable feature in the arrangement of a miscellany is that the reader should be able to find his way about it easily, and what is more, be able to retrace previous steps without much perplexity. Sub-headings have therefore been

freely used in the full list of titles that follows, and these pointers have been arranged in alphabetical order. This brings about some juxtapositions strange to formal science, but then, do not Fred Archer the jockey, Lord Armstrong the armament maker, and Matthew Arnold the poet, rub shoulders in the *Dictionary of National Biography*?

A large amount of space might have been saved by leaving out the "performance" guarantees, but these, it is hoped, will be helpful and encouraging, like "footprints on the sands of time."

The Chairman and Committee of the Science Masters' Association acknowledge with sincere gratitude all the help that they have received from members of the Association, from University teachers and from others interested in the development of science teaching in schools.

G. H. J. A.

City of London School,
E.C.4.

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CHEMISTRY

ALLOYS

213. RECALESCENCE OF STEEL AND OTHER EFFECTS

E. H. Duckworth

THE apparatus consists of a 39-in. length, AB, of steel piano wire, size 23 I.W.G., diameter 0·024 in. It is stretched between terminals soldered to two supports, AH and BM, consisting of $\frac{1}{4}$-in. diameter stair rods, 2 ft.

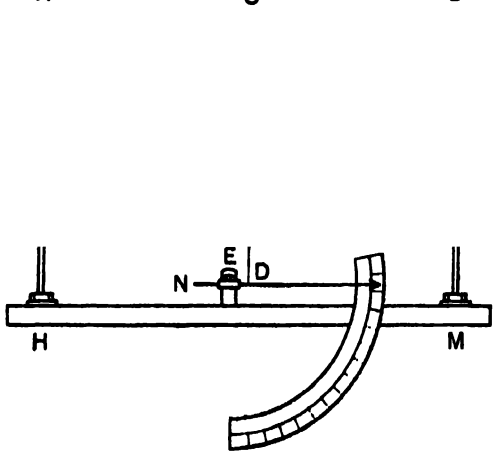


FIG. 176.

long. A piece of fine copper wire, size 36 I.W.G., is twisted round the steel wire at C and connected to a magnifying pointer at D. The pointer is made from a piece of aluminium wire, size 15 I.W.G. It is pivoted at E and measures, from E to the paper arrow tip, 36 cm., from E to D 2 cm., and from E to N 8 cm.

On passing a current of 10 amps. through the steel wire, it becomes red hot. The wire expands and the pointer moves to the bottom of the scale. On switching off, the wire contracts. This is shown by the arrow, but at a temperature of about 740° C. the steel wire gets hot again of its own accord. The arrow shows a sudden downward movement through an arc of about 6 in. length, then once more, contraction.

The apparatus can also be used to show that, on heating, the rate of expansion is not uniform ; that at a certain temperature during the process of heating, the absorption of energy is so rapid that actual contraction occurs.

By holding a magnet near the wire, it is easy to demonstrate to a class that steel is non-magnetic when red hot. A suitable current can be obtained by connecting the wire in series with a 10-amp. arc-lamp, or large gas-filled lamp. It can be connected direct to a 50-volt supply. A transformer is useful.

214. MELTING POINTS OF LEAD-TIN ALLOYS

E. Nightingale

A simple thermocouple of iron and nickel is made by passing wires of these metals through bent glass tubes,

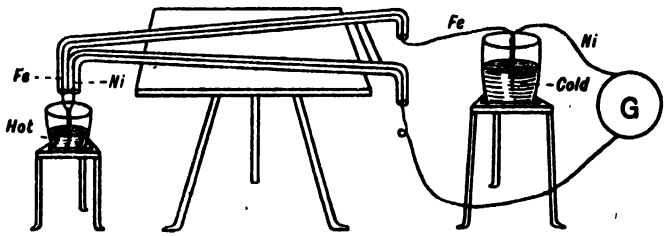


Fig. 177.

about 12–18 in. long, the whole being kept rigid by means of a third cross-piece of glass to which the others are fastened by wire. Such a thermocouple is conveniently hung up after use.

The thermocouple is first calibrated by placing it in series with a D'Arsonval galvanometer or other sensitive instrument and placing the hot junction in boiling water, melting sulphur, solidifying lead and tin in turn, the cold junction meanwhile being kept in a cold-water bath at a known temperature, or in melting ice in a thermos flask. From these observations, a graph is obtained showing deflections and temperature differences to correspond.

A series of alloys is made up by weighing out into separate small unglazed or graphite crucibles amounts corresponding to the molecular proportions Pb_4Sn_4, Pb_4Sn_3, etc., to $PbSn_4$. These should be labelled and kept for future use.

Cooling curves are next obtained for (*a*) pure tin, (*b*) pure lead, (*c*) each alloy in turn. From the observations the curves are all plotted on one large sheet of squared paper, and each is carefully labelled. An intelligent boy will at once note the following facts :

(*a*) Pure metals give a well-marked horizontal portion, indicating the setting point.

(*b*) In the alloy curves there is a noticeable break in continuity, which is not horizontal. When the alloy is rich in lead, this break begins at a temperature lower than the setting point of lead. The break is not horizontal because, as more lead separates out, the mixture becomes richer in tin, so the melting point falls gradually. The teacher can guide the student to a correct understanding of this phenomenon.

(*c*) Following this stage another horizontal part is noticed, which may be long or short according to the constitution of the mixture. This part is seen to be always at the same point. It gives the setting point of the eutectic mixture.

(*d*) By plotting the first setting point (*b*) against the molecular composition, a curve is obtained which shows a minimum—this minimum is the eutectic, and its constitution may be found from the graph.

CALORIFIC VALUE

215. A SIMPLE GAS CALORIMETER

T. E. W. Browne

This calorimeter can be easily made from an old 500-c.c. copper beaker, and gives results of sufficient accuracy for elementary work on fuel calorimetry. A hole is made in the bottom of the beaker to take a short length of $\frac{1}{2}$-in. copper tube. The upper end of this tube is closed by soldering over it a disc of copper, and a hole is made just below this disc to take a length of $\frac{3}{16}$-in. copper pipe.

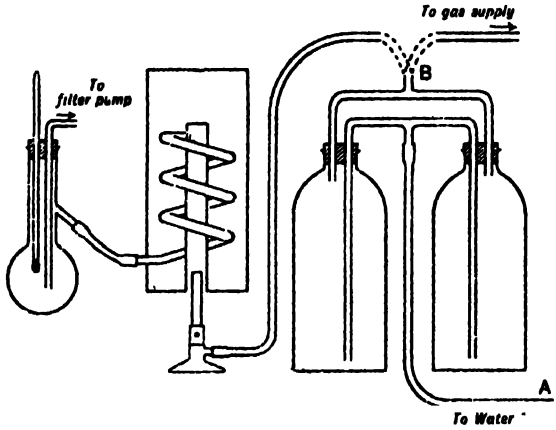


FIG. 178.

When soldered in position, this pipe is coiled round in the form of a worm, care being necessary to obtain gradual bends and an absence of kinks. The wide tube is then soldered in place, the free end of the worm being soldered through a hole made in the side of the beaker, as shown.

For an actual determination, two Winchester quarts, fitted as shown in the figure, are required. These are filled completely, first with water, and then with coal gas (or other gas to be examined) by allowing the water to syphon out through A, with the tube B connected to the

gas supply. All corks and joints must, of course, be gas-tight.

The tubes are then closed with clips, and the working connections are made, A to the water supply and B to the Bunsen. The Bunsen is inserted into the tube at the bottom of the calorimeter, which should previously have had its water equivalent determined and have been filled with a known amount of water at a known temperature. Gas is driven through the Bunsen by turning on the water supply, and the Bunsen is lighted. The side exit tube of the worm is then connected, via a small distilling flask, to a filter pump, which is kept sucking at such a pace that the thermometer in the flask indicates no rise in temperature.

The highest temperature attained by the water is noted, adequate stirring being essential, and the volume of gas used is found by measuring the capacity of the bottles for water. The calculation is obvious. For interest, the result should be converted into British Thermal Units per cubic foot and compared with the British Gas Standards. It should fall between 450 and 500 B.T.U.s per cubic foot.

CATALYSIS

216. EFFECT OF WATER ON THE COMBUSTION OF CARBON MONOXIDE

Cambridge, 1922

An aspirator full of carbon monoxide is prepared, and connected with another aspirator full of water, to give the necessary pressure. This supplies a carbon monoxide flame burning at a horizontal jet. Two similar litre flasks are taken, one of which contains 20–30 c.c. of concentrated sulphuric acid, and has been corked and shaken for some time to dry the air in it. On taking out the cork of this flask and placing the flask over the jet, the flame at once goes out because the air is too dry. On relighting the jet

and putting over it a flask containing ordinary air, not dried, the flame continues to burn.

217. INTERMEDIATE COMPOUND THEORY OF CATALYSIS AND OF A DELAYED REACTION

F. A. Philbrick

In the presence of a trace of cobalt salt as catalyst, a boiling solution of sodium potassium tartrate is rapidly oxidised by hydrogen peroxide. A bright green intermediate compound is formed and then decomposes, leaving the pink cobalt salt unchanged at the end of the experiment.

Dissolve about 7 grams of Rochelle salt in 60 c.c. of water in a beaker and boil. Then add a solution of hydrogen peroxide—say, 20 c.c. of the 20-volume solution, and heat to boiling. The mixture is fairly stable and there is little or no visible evolution of gas. Now add enough of a solution of cobalt chloride to colour the solution distinctly pink (about 0·1 gram of the hexahydrate) and place the beaker against a white background. After a distinct induction period, the pink colour begins to disappear, and is succeeded by an intense green, while carbon dioxide mixed with oxygen is vigorously given off. After a minute or two, the green colour fades in its turn and is replaced by pink.

By reducing the quantity of tartrate (say, to 1 gram), the induction period can be prolonged to ten minutes or more, and a lower temperature has the same effect; at 25°, induction periods of more than an hour have been observed. The green intermediate can be preserved for examination by rapid cooling at the right moment ("freezing the equilibrium").

218. THE SENSITISING EFFECT OF SILVER

T. Slater Price

This sensitising effect of silver may be illustrated by the following experiment, originally due to Becquerel.

A piece of printing-out paper is exposed under a negative until a weak image is formed. The negative is then taken away and the whole paper exposed directly to sunlight under a yellow glass. The image then prints up to full strength. In the first exposure under the negative, the amount of silver formed depends on the exposure received. In the second exposure, the catalytic effect of this silver comes into play and will be greater at those points where more silver was produced in the first exposure.

CHEMI-LUMINESCENCE

219. OXIDATION OF *o*-AMINOPHTHALIC CYCLIC HYDRAZIDE

British Drug Houses

Dissolve 1 gram of *o*-aminophthalic cyclic hydrazide in 100 c.c. of 5 per cent. sodium hydroxide solution and add ten drops of hydrogen peroxide (10 volumes). Allow this solution to fall into a concentrated solution of potassium ferricyanide (made alkaline with sodium hydroxide), or into a solution of sodium hypochlorite (about 1 per cent.). Each drop produces a brilliant bluish-white pearl of light which will render objects in a dark room visible. In sunlight the glow is visible as a blue fluorescence. The effect is very striking indeed if the beaker into which the *o*-aminophthalic cyclic hydrazide solution is dropped is placed in a box with one side removed and painted dead black on the inside.

Beautiful, though less bright, effects may be produced by mixing large volumes of weak solutions of the hydrazide (containing a little hydrogen peroxide) and sodium hypochlorite. The glow is still perceptible in the dark at dilutions of 1 in 100,000,000.

REFERENCES.—T. Curtius and A. Semper, *Ber.* 1913, 46, 1170; H. O. Albrecht, *Zeit. für physikal. Chemie*, 1928, 136, 321.

COLLOIDAL STATE

220. COLLOIDAL SILVER

T. Slater Price

Lüppo-Cramer showed how the transmission colour of a silver sol varies with the size of the particles.

The method of the experiments is as follows : A nucleus sol of silver, containing very fine particles, is prepared. To separate and equal volumes of gelatin solutions, each containing the same weight of silver nitrate, varying quantities of the nucleus sol are added. Each of these mixtures is then reduced with the same quantity of hydroquinone, the reduced silver depositing on the particles from the nucleus sol. The ultimate size of the particles in the final sols obtained will thus depend on the amount of nucleus sol taken. The larger the final particles, the more is the transmission colour displaced towards the blue end of the spectrum.

Nucleus Sol.—Ten c.c. of a 10 per cent. solution of yellow dextrin, 10 c.c. of 10 per cent. sodium hydroxide, 22·5 c.c. of water and 7·5 c.c. of 10 per cent. silver nitrate are mixed, the mixture being diluted to 1,500 c.c. after half an hour. This nucleus sol is practically optically clear, transmitting brownish-red light, which becomes pure yellow in very thin layers or on high dilution. It is best to prepare it fresh on the day it is required.

Coloured Sols.—Ten grams of a good photographic gelatin are soaked in 5–6 changes of distilled water over a period of 24 hours, after which they are made up to a 2 per cent. solution, and 20 c.c. of a 10 per cent. solution of silver nitrate added. To separate quantities of 50 c.c. of this solution, warmed to 30°, are then added respectively (*a*) 0·25 c.c., (*b*) 1 c.c., (*c*) 2·5 c.c., (*d*) 5 c.c., of the nucleus sol, followed by 0·25 c.c. of a 1 per cent. solution of sodium phosphate, and then 2 c.c. of a 10 per cent. alcoholic solution of quinol, the latter being added in drops, well mixing meanwhile. After 20 minutes the reaction is complete,

and the transmission colours are (*a*) blue, (*b*) violet, (*c*) red, (*d*) yellowish red. If the sols are diluted with an equal volume of 10 per cent. gelatin, coated on glass (a lantern-slide cover-glass) and dried, the colours become finer, but are displaced towards the blue end of the spectrum. On moistening, the original colours will be restored.

It may be that with the above proportions the red olours are not obtained. If this is the case, it is only ecessary to repeat the experiments, using further uantities of the nucleus sol; for example, 10, 20 and D c.c.

221. LIESEGANG RING FORMATION

Birmingham, 1922

Very perfect silver chromate rings, illustrating the eriodic formation of precipitates, were very simply emonstrated by placing in a test-tube a warm solution btained by mixing 100 c.c. of 5 per cent. gelatine solution and ·05 gram of potassium dichromate in a little water. This solution is then allowed to cool and set, after which

c.c. of a solution of silver nitrate (8·5 per cent.) is poured over the top, and the whole left undisturbed. In time the separate rings of silver chromate appear, illustrating perfectly the periodic nature of the precipitation under the conditions of the experiment.

The experiment can easily be modified for class demonstration with a lantern, by placing some of the potassium-dichromate-gelatine mixture on a slide, and after it has set, dropping on a very small amount of silver nitrate solution in the centre. In this case the rings produced are concentric.

COMBUSTION AND OXIDATION

222. OXIDATION OF ALUMINIUM

F. A. Philbrick

Warm a piece of aluminium foil in a solution of mercuric chloride for half a minute or so, until the appearance of

the surface of the metal shows that amalgamation has taken place. Then wash the metal, dry it with filter paper and pass it from hand to hand; its spontaneous oxidation soon makes it too hot to hold.

The aluminium amalgam is the best desiccating agent for alcohol.

223. OXY-AMMONIA FLAME

D. Ll. Hammick

The oxy-ammonia flame can be produced by leading ammonia and oxygen into the appropriate inlets of any ordinary blowpipe and igniting the mixture at the jet. The flame may be allowed to play upon a water surface or upon ice, and the formation of nitrates and nitrites demonstrated.

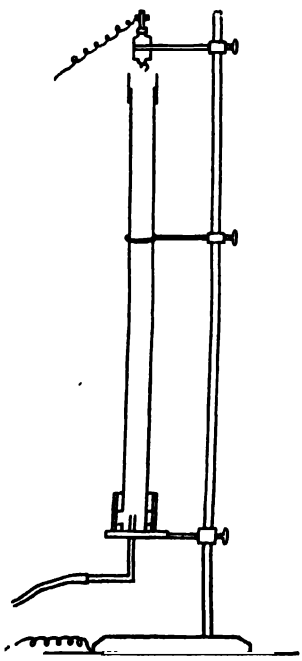


FIG. 179.

224. EXPLOSION WAVE AND BACK-FIRING OF A BUNSEN BURNER

E. H. Duckworth

An effective way of demonstrating the above is to make a large Bunsen burner out of a glass tube, 40 in. long and $1\frac{3}{4}$ in. diameter (Fig. 179). The bottom of the tube can be arranged to fit into a short metal tube with air-holes. By bending a piece of thin sheet metal and soldering the joint, a sleeve with corresponding air-holes can be arranged to slip round the first metal tube. This provides for air adjustment. The first metal tube is soldered to a brass base-plate, through

which enters a small metal tube, $\frac{1}{4}$ in. diameter, for the supply of gas.

At the top of the glass tube is arranged a sparking plug, worked by a small coil. On starting the spark coil and turning on the gas, a series of explosion waves can be made to form over and over again. If the gas is turned ll on and the air-holes are open, a large Bunsen flame is ned at the top. When the gas is turned down wly, a point is finally reached when the upward city of the gas-air mixture becomes less than the nward velocity of the explosion wave, and the ner back-fires.

It is advisable to wire on a sheet of mica, tied in indrical form, to the top of the glass tube, to prevent e latter being cracked by the flame.

25. FLAME CAP FORMED IN A MIXTURE OF AIR AND COAL GAS

J. A. Wenden

A 7-lb. biscuit tin, painted dead black inside, has a ole, A, about 1 in. in diameter, cut in the bottom. A iece of brass tube, B, about $\frac{3}{8}$ in. in diameter, is soldered n. In one face a piece, C, is cut out and a piece of black aper stuck over it. In the opposite face a large window s made. The glass can be supported by bending back he tin. E is a Bunsen with tube and jet removed. F is an ordinary Bunsen. Some means of sucking air through is attached to B (a filter pump or a vacuum cleaner can be used). E is lit and the gas turned down till a luminous tip just shows. F is then turned on very slowly, and a pale-blue cap of flame appears over E, increasing in size as the percentage of gas increases. General inflammation occurs at a percentage of gas between 7 and 8, and the paper serves as a safety device in case of this occurring.

Since the cap is very pale, it can only be demonstrated close up and in a darkened room.

This experiment was shown in the Mining Department at Birmingham, a rather more elaborate apparatus being

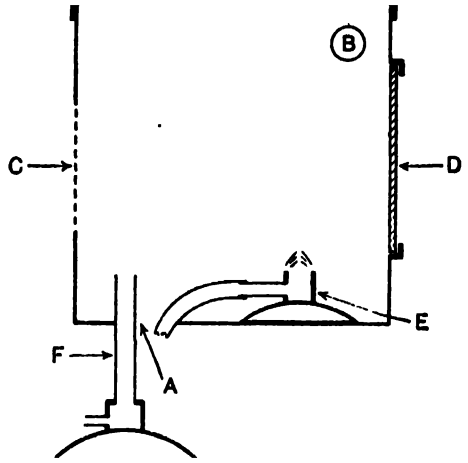


FIG. 180.

used, and the apparatus described above was suggested by a member of the staff, and has proved quite easy to use.

CRYSTALS

226. PRECAUTIONS NECESSARY TO OBTAIN GOOD CRYSTALS

D. B. Briggs

In making a collection of crystals, it is found that some substances show a more marked tendency to yield large, well-shaped specimens than others. Many crystals develop in such a manner that certain faces become unduly elongated at the expense of others, giving rise to a needle-shaped "habit." When this is the case, it is often a matter of some difficulty to obtain really satisfactory results. Again, those crystalline bodies which are deliquescent, or efflorescent, or which are readily oxidised or decomposed in the atmosphere, do not readily lend

themselves to taking a place in any permanent collection.

Method 1.—*To obtain good crystals of blue vitriol.*

Note.—The solubility of copper sulphate, $CuSO_4 . 5H_2O$, in water is 36·95 at 10° C., and 42·31 at 20° C., referred to 100 grams of the solvent water.

Measure out 100 c.c. of distilled water into a beaker, and add to it 43 grams of well-powdered blue vitriol. Stir the mixture well, and heat on wire gauze until complete solution has been effected. Filter (even if the solution appears to be clear) into a perfectly clean, warmed, flat crystallising dish standing on a pad of felt. The size of the dish should be so chosen that the liquid fills it to a depth of about 1 in. Then remove the dish, after covering it lightly with paper, and allow it to stand overnight on the felt base in a cupboard which is free from draughts, and where a fairly equable temperature can be relied on. As soon as possible next morning—especially in summer, when a considerable temperature rise may occur—remove any crystals which have separated, and dry them on filter paper, taking care not to injure any of the faces. Meanwhile, filter the solution into a warmed crystallising dish, and after having selected one or two of the most perfectly formed crystals (which may be quite small), replace them in the clear liquid after it has cooled. During the course of the next few days, turn the growing crystals so that different faces in succession are in contact with the bottom of the pan. In order to allow for removal of solid from the solution, add a few drops of warm, concentrated copper sulphate solution to the main bulk, after removal of the crystals. Then, when the solution is quite cold, again replace the crystals. This process may be repeated from time to time when necessary. It is absolutely essential during the growing of the crystals to prevent temperature fluctuations as far as possible. and to exclude dust.

Method 2.—A method which gives excellent results in the growing of crystals is to place the crystallising dish

containing saturated solution and growing crystals in a large covered glass vessel, in which is an open basin filled with strong sulphuric acid. (Or a vacuum desiccator may be employed.)

Method 3.—If very volatile solvents, such as carbon disulphide, ether, etc., are employed, it is best to make a saturated solution at room temperature, and after filtration into a slightly warmed crystallising dish, to cover the latter with a piece of stout cardboard in which several holes have been pricked. Slow evaporation will then commence, and good crystals may be obtained.

227. EXHIBITION OF CRYSTALS

D. B. Briggs

Method 1 (see Fig. 181).—A large blanket pin is pushed through the middle of a cork, and a small spot of wax (or quick-setting gum) is placed on one face of the crystal to be exhibited. The head of the pin is then heated *slightly* and placed on the wax, where it is kept in a vertical position until the melted wax sets again. The cork is then inserted into a flat-bottomed specimen tube, and the pin adjusted so that the attached crystal is free from the sides of the vessel, and at a convenient height. The pointed end of the pin sticking through the cork is then covered with a thin disc of cork on which a descriptive label has previously been gummed. Finally, the specimen tube is fixed on to a sheet of stiff white cardboard.

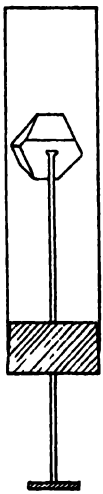


FIG. 181.

Method 2 (see Fig. 182).—Four blanket pins are inserted into a cork so that the heads are at the same height and the sharp

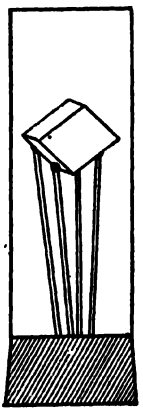


FIG. 182.

ends are embedded in the cork. The heads are then covered with a small amount of cotton wool, and the crystal put on the prepared support. The bottom (wide end) of the cork is then gummed on to a piece of stiff white cardboard, and the glass specimen tube fitted carefully on to the cork.

228. PREPARATION OF SLIDES

D. B. Briggs

Method 1.—A microscope slide is cleaned thoroughly with a mixture of chromic acid and strong nitric acid, followed by a thorough rinsing with pure water, and then air-dried. One drop of a *very slightly* supersaturated solution of the salt under examination is then placed in the middle of the slide from the end of a glass rod. The crystals can then be examined under the microscope as they form and grow.

Method 2.—For permanent records, select a few perfectly developed crystals which are just large enough to be seen properly with the naked eye. Put them in the middle of a *celled* microscope slide and smear round the edge of the cell with gold size. Put on a cover slip, and set aside for several days until the size is properly set. (If this process is not complete, the crystals may suffer.)

uch samples are very convenient to have. They can be sily examined with the naked eye, or better still, with small pocket lens, and in addition, it is possible to keep ich easily decomposed crystals as ferrous sulphate, c., without appreciable decomposition setting in.

29. TO ILLUSTRATE THE SEVEN CRYSTAL SYSTEMS

D. B. Briggs

The numbers below refer to the mass of solid, whose ormula is given, which might conveniently be dissolved n 100 c.c. of water when making crystals according to the nethod described for blue vitriol.

Cubic System:

Potash alum, $K_2SO_4 . Al_2(SO_4)_3 . 24H_2O$, [16 grams].
Lead nitrate, $Pb(NO_3)_2$, [56 grams].
Chrome alum, $K_2SO_4, Cr_2(SO_4)_3 . 24H_2O$, [25 grams].
Barium nitrate, $Ba(NO_3)_2$, [70 grams].

Tetragonal System:

Mercuric cyanide, $Hg(CN)_2$, [14 grams].
Potassium dihydrogen phosphate, KH_2PO_4, [45 grams].

Rhombic System:

Potassium chromate, K_2CrO_4, [65 grams].
Sulphur (from carbon disulphide).
Potassium sulphate, K_2SO_4, [12 grams].
Magnesium sulphate, $MgSO_4 . 7H_2O$, [130 grams].

Oblique or Monoclinic System:

Potassium ferricyanide, $K_3Fe(CN)_6$, [42 grams].
Ferrous ammonium sulphate, $FeSO_4(NH_4)_2SO_4 . 6H_2O$, [38 grams].
Nickel ammonium sulphate, $NiSO_4 . (NH_4)_2SO_4 . 6H_2O$, [12 grams].

Anorthic or Triclinic System:

Copper sulphate (blue vitriol), $CuSO_4 . 5H_2O$, [43 grams].
Potassium dichromate, $K_2Cr_2O_7$, [12 grams].

Rhombohedral or Trigonal System:

Sodium nitrate, $NaNO_3$, [90 grams].
Natural crystals of calcite and quartz.

Hexagonal System:

Strontium antimonyl tartrate (celled slide).
Lead iodide (celled slide).
Ferrous chloride (celled slide).

230. TO ILLUSTRATE THE PRINCIPLES OF ISOMORPHISM

D. B. Briggs

(1) Excellent examples of crystals of the isomorphous series whose general formula is—

$M_2SO_4 . N_2(SO_4)_3 . 24.H_2O$—the Alums—

may be made. M may be represented by potassium and by ammonium, whilst N may be aluminium, chromium or ferric iron.

(2) A series may be made of the isomorphous group—$M_2SO_4 . RSO_4 . 6H_2O$—the Monoclinic Double Sulphates, where M may be potassium and ammonium, and R copper, ferrous iron, cadmium, cobalt, nickel, manganese, magnesium or zinc.

231. MIXED CRYSTAL FORMATION

D. B. Briggs

Make several solutions containing mixtures of zinc ammonium sulphate and nickel ammonium sulphate in varying proportions. Crystallise in the usual manner, and obtain a series of mixed crystals which show different tints of green according to the relative proportion of nickel ammonium sulphate in them.

Repeat the experiments with other combinations of a colourless double sulphate (magnesium ammonium sulphate can be recommended) and a coloured double ammonium sulphate, such as one containing cobalt, copper or iron.

Further examples can be shown by doing similar experiments in the alum series above, but there it must be remembered that any alum containing chromium must not be heated much above 30° C., or there is the danger of obtaining green solutions difficult to crystallise.

232. ISOMORPHOUS OVERGROWTHS

D. B. Briggs

(*a*) A crystal of nickel ammonium sulphate is grown in a saturated solution of zinc ammonium sulphate, when the latter forms a colourless sheath round the former.

(*b*) Iron alum can be obtained in good regular octahedra. Make experiments to illustrate the fact that such crystals may be coated with overgrowths of other alums.

(*c*) Make a good crystal of alum, and coat it with successive layers of other alums by growing in saturated solutions. Then grind it on a glass plate, wetted with water, so as to obtain a sectional view showing the different layers.

233. THE SIMILARITY OF SOME IONIC COLOURS IN SOLUTION AND IN THE SOLID CRYSTAL

D. B. Briggs

Make a collection of crystals to illustrate this.

Suggestions :

Ferrous ammonium sulphate, $FeSO_4(NH_4)_2SO_4 . 6H_2O$, [38 grams].

Copper sulphate, $CuSO_4 . 5H_2O$, [43 grams].

(Do not boil.) Manganese sulphate (this is difficult), $MnSO_4 . 5H_2O$, [130 grams].

Nickel sulphate, $NiSO_4 . 7H_2O$, [85 grams].

Potassium chromate, K_2CrO_4, [65 grams].

(Do not boil.) Potassium permanganate, $KMnO_4$, [7 grams].

Cobalt ammonium sulphate, $CoSO_4(NH_4)_2SO_4 . 6H_2O$, [24 grams].

Potassium ferrocyanide, $K_4Fe(CN)_6 . 3H_2O$, [34 grams].

Copper acetate, $(CH_3COO)_2Cu . H_2O$, [10 grams].

(Do not boil.) Copper formate, $(H . COO)_2Cu$, [14 grams].

234. DIFFERENT METHODS OF MAKING CRYSTALS

D. B. Briggs

(1) *By Means of Solvents.*—Crystallise sulphur from carbon disulphide and from ethyl acetate, and show the difference in habit.

Show the peculiarities of habit in the crystallisation of ammonium chloride, mercurous nitrate, common salt

(from pure water and from water containing various impurities, such as caustic potash, etc.).

(2) *By Fusion and Solidification.*—Use *p*-nitroaniline, metallic antimony and potassium dichromate.

(3) *By Sublimation.*—Heat a few crystals of iodine in a large clock glass, covered by a similar one to it.

Note the formation of good, small crystals on the upper glass.

Repeat the experiment with anthraquinone, placing some of the latter in a crucible which is completely hidden by an inverted evaporating dish whose upper surface is kept cool by wet filter papers. More intense heating is needed in this case.

(4) *By Deposition in Solution.*—Hang strips of zinc in solutions of mercuric chloride, stannous chloride, silver nitrate, etc.

(5) *By Electrolysis*, e.g. copper from copper sulphate.

(6) *By Salting Out.*—This is illustrated by :

(*a*) Adding strong hydrochloric acid to saturated salt solution.

(*b*) Adding strong nitric acid to saturated barium nitrate solution.

In the two cases, the crystals obtained are small, and should be examined under the microscope.

(7) *By the Interaction of Gases.*—Pass chromyl chloride vapour and ammonia gas into a large flask, and note the formation of crystalline ammonium chromate.

Repeat the experiment, using carbon dioxide in place of chromyl chloride, and illustrate the formation of ammonium carbamate.

DISTILLATION

235. A NEW STILL-HEAD

S. F. Dufton

The still-head is constructed, as shown in the diagram, of glass tubing into which are fitted lengths of closed

tubing, wound helically with wire. The efficiency is greater than that of all other still-heads for small quantities of liquid.

The dimensions for such separations as benzene and toluene, or alcohol and water, in quantities of 100 c.c. and upwards, may be as follows :

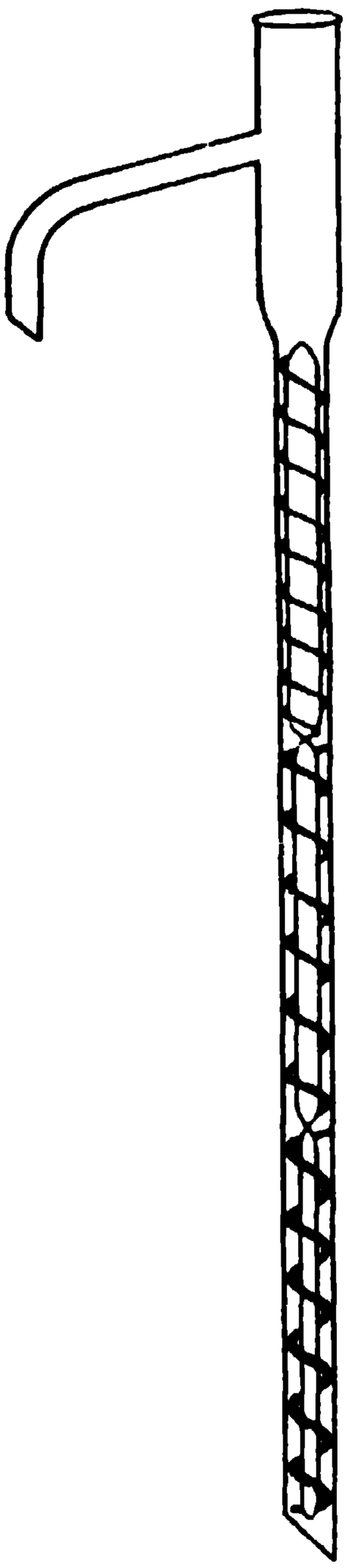


Fig. 183.

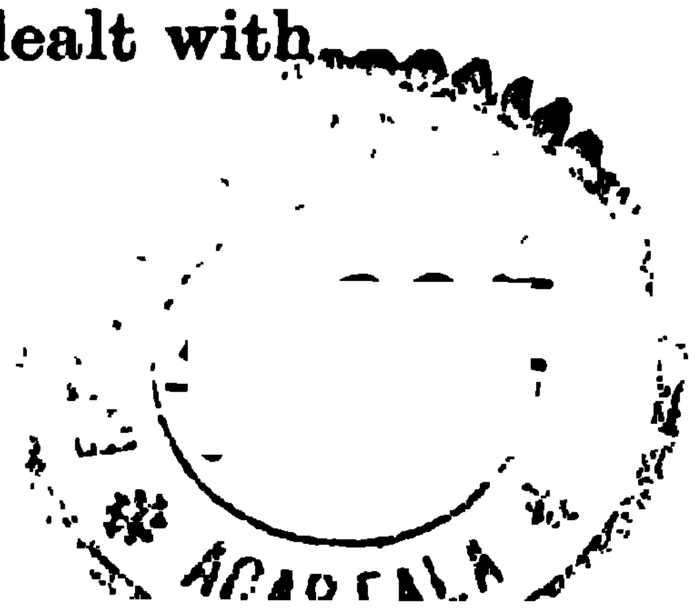
Length of column	about 120 c.m.
Internal diameter	about 16–18 mm.
Wire of top section	about 0·8 mm. diameter
,, bottom section	about 1·4 mm. diameter

Pitch of helix about 12 mm. at the top, rising to 22 mm. at the bottom.

The exposed part of the column should be lagged to a thickness of about 2 in. with cotton wool wadding, held in position with tape or, better, with asbestos yarn.

With such a column, a mixture of 50 c.c. benzene and 50 c.c. toluene, distilled with an initial velocity of about 4 c.c. per minute, yields, with constant temperature at the head, about 45 c.c. of benzene. If the flame be not raised, the distillation slows down and stops, when no more benzene can be extracted. On raising the temperature, a small amount of mixture comes over, and when the thermometer at the top shows the boiling point of toluene, the distillation may be stopped ; about 45 c.c. of toluene remain in the flask.

By reducing the diameter of the tube and annulus, a closer separation may be made, and smaller quantities, down to 10 c.c. or less, may be dealt with.



A similar arrangement serves as a most efficient washer for gases.

ELECTROLYSIS

236. ELECTRODES AND HOLDERS FOR ELECTROLYSIS EXPERIMENTS

G. N. Pingriff

One of these is shown in Fig. 184 ; it is very useful both in experiments on the conductivity of solutions with a

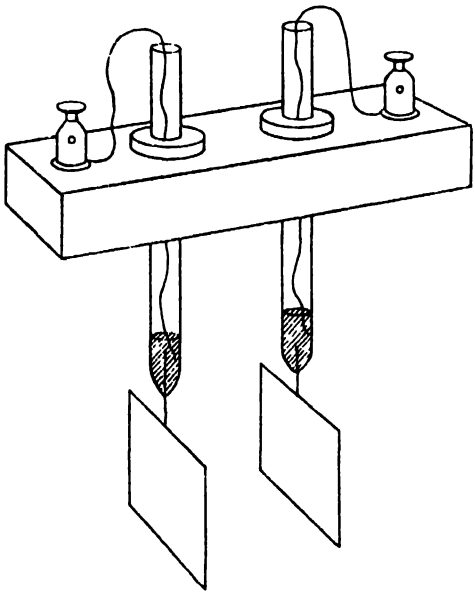


Fig. 184.

lamp in series and also in electro-analyses. For the latter purpose, the two electrodes are joined by a copper wire dipping into the mercury and together form the anode, while the cathode is a flag-shaped piece of metal designed to go between the platinum electrodes. This cathode, for most purposes, can be made of copper, and should be

provided with a hole near the top for suspension from a balance hook.

237. APPARATUS FOR CLASS WORK IN ELECTROLYSIS

F. W. Hunt

Electrolysis is carried out in U-tubes of rather wide bore, with limbs bent close together. The rubber stopper

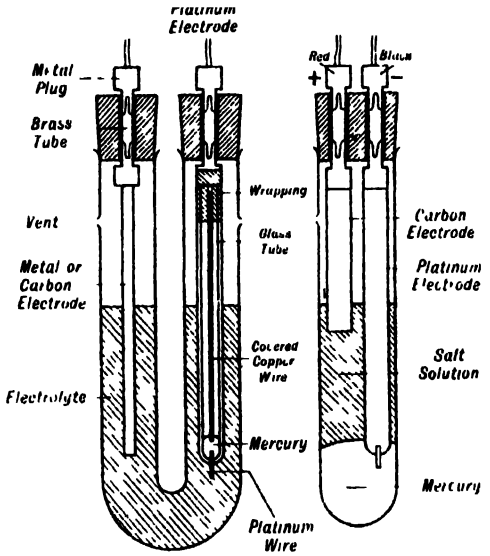


FIG. 185.

for each limb is fitted with a hollow brass tube. Interchangeable electrodes are used, each of which is fitted with a standard plug which fits the tube in the stopper.

Power is obtained from a distribution board, which is fitted with a series of sockets Leads of double flex plug in, at one end to the distribution board, and at the other end to the brass tubes in the stoppers. In this way, power from one board can be distributed to six subsidiary positions, at each of which electrolysis is simultaneously

carried out. The distributing board can either be suitable for use with D.C. mains or with a 6-volt accumulator. Positive plugs and sockets are red, negative ones black. Supervision before electrolysis starts is thus simple.

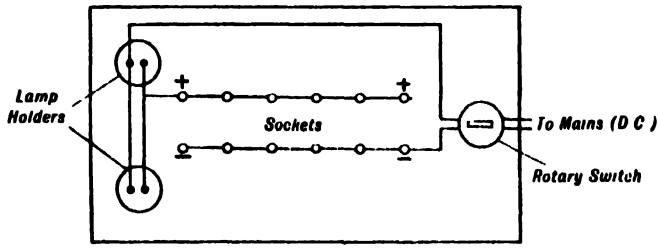


FIG. 186.

Carbon, copper, zinc and platinum electrodes will enable all the more simple cases to be studied. The platinum electrode has a very short length of platinum fused through one end of a piece of glass tube, electrical connection being made with the plug by means of wire and a globule of mercury A mercury electrode can readily be obtained by using a test-tube of suitable dimensions, fitted with a double-bored stopper. Contact with the mercury at the bottom of the tube is made with a platinum electrode.

Three distributing boards and four pairs working from each board is a convenient arrangement. Suitable electrodes and solutions are distributed, connections made and checked, and the whole class carries out the first experiment. At the end of ten minutes, results can be noted and gases tested for. The next experiment is then dealt with in a similar manner. Since each board is fitted with a switch, it is unnecessary to touch any part of the apparatus while the current is on. Any possible danger is thus eliminated.

EXPERIMENTAL WORK

Non-Electrolytes.

Distilled water. Carbon electrodes.

No perceptible action ; lamp does not light.

Decomposition of Water.

Dilute sulphuric acid. Platinum electrodes.

Hydrogen liberated at cathode and oxygen at the anode.

The oxygen gives a satisfactory test with glowing string, but it is difficult to get the hydrogen "pop" before the gas escapes from the tube.

Primary Reactions.

Zinc chloride. Carbon anode; zinc cathode.

Zinc crystals are obtained on the cathode. Chlorine can be tested for in the anode tube.

Concentrated hydrochloric acid. Carbon electrodes.

Gases can be tested for as above.

Secondary Reaction.

Sodium sulphate. Platinum electrodes.

Add an indicator to the solution. (B.D.H. Universal Indicator gives the cleanest colours.) Besides the evolution of gases, the anode limb shows the formation of free acid, and the cathode limb free alkali.

Commercial Processes

Electroplating.

Copper sulphate. Copper electrodes.

No evolution of gas. The anode dissolves and copper is deposited on the cathode.

Manufacture of Caustic Soda.

Salt solution in the "test-tube." Carbon anode; mercury cathode.

Chlorine is evolved at the anode and sodium amalgam formed at the cathode. To illustrate the Castner-Kellner process, pour the amalgam into water.

Ammonium amalgam is obtained by pouring the amalgam into a solution of ammonium chloride.

Ammonium amalgam is formed directly at the cathode by the electrolysis of ammonium chloride solution in the above apparatus.

General Notes

Solutions of normal strength will be found suitable.

The polarity of the mains must be tested so that the red sockets on the board are positive. This can be utilised as a class experiment, if desired.

A carbon lamp, passing about 0·8 amp., is suitable for four subsidiary positions. A smaller lamp in addition will be required for six positions. A metal filament lamp will be found satisfactory for a single position.

Crystals of tin and lead can easily be obtained from suitable solutions.

Any other electrodes can be fitted with plugs, if required.

A 6-volt accumulator can be used for all the experiments enumerated above. Some of the results will be slower.

Quantitative results are not to be expected.

The apparatus is manufactured and sold by Messrs. Townson & Mercer, London.

238. CELLS FOR ELECTROLYSIS

Cambridge, 1929

The cells for these experiments are most conveniently constructed by compressing a piece of pressure tubing between two glass plates, as described by Newth (*Chemical Lecture Experiments*, pp. 311, *sqq.*).

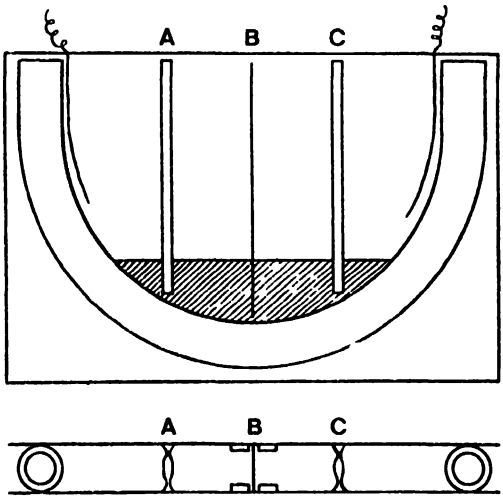


Fig. 187.

The porous partitions (A, C, Fig. 187) are made from filter paper (Newth, p. 313), and it is an advantage to run in molten paraffin wax to form the bottom of the cell. The shaded portion in the figure (which represents the elevation and section of such a cell) shows the paraffin wax.

239. THE TRANSFERENCE OF IONS

Cambridge

To demonstrate the transference of ions through the electrolyte, a cell is needed, with a central partition, B (see Fig. 187), of the thinnest platinum foil (costs only a shilling or two). This is held in place by cementing on four strips of glass (as shown in the section at B) with Canada balsam, to form two grooves to carry the platinum. If plenty of balsam is used and the strips are pushed up, the platinum is held water-tight (it is most important that it should be absolutely water-tight).

On filling the cell with a solution of sodium sulphate containing a little phenol phthalein, red colour (due to sodium ions) appears both at the cathode and *at the side of B away from the cathode*. On reversing the current, the colour disappears and appears on the other side of B and at the other electrode.

240. ELECTROLYTIC OXIDATION AND REDUCTION

Cambridge

In showing electrolytic oxidation and reduction, cells are used without the central platinum partition, B (Fig. 187). For reduction, use a mercury cathode and indigo solution to which a few drops of chrome alum solution have been added. For oxidation, use a solution of manganous sulphate, with a few drops of nitric acid, and note the immediate formation of permanganic acid.

Platinum foil electrodes are used for all three experiments. A potential difference of 6 volts is sufficient for the transference experiment; for the oxidation and reduction, 12 volts will give more rapid change.

Note.—In absence of platinum, it would be worth while trying pure nickel for the transference experiment.

241. CHANGES IN CONCENTRATION AROUND THE ELECTRODES

H. E. F. Micklewright

These may be demonstrated by throwing an image of the cell on a screen, when changes in the densities of the liquid round the anode and cathode are shown by the movements of the electrolyte. Copper sulphate solution, with copper electrodes, and lead nitrate solution, with platinum electrodes, give good results. In the latter case, the effect of reversing the current after a good growth of lead crystals has been obtained is most striking.

242. ISOLATION OF SODIUM

E. R. Martin

The following is a simple repetition of Davy's classic experiment[1] which led to the isolation of the alkali metals.

From a tin canister cut a circular disc of 3 in. diameter, bending it slightly to form a very shallow saucer. After cleaning the concave surface with emery paper, loosely attach a wire to the rim and then, by means of a split cork held in the jaws of a clamp on a retort stand, keep wire and tin in close contact.

Wind another wire round a clean knitting needle, and fasten the latter in another split cork in a vertical position over the centre of the tin disc with a second lamp. This cork acts as an insulator as well.

[1] Described in *Phil. Trans.* for 1808. Read November 19th, 1807.

Lastly, connect both wires through a lamp rheostat to the electric light main (this must be a direct current circuit), making the needle the cathode and the disc the anode.

Cut off a small stick of caustic soda, place it in the saucer, and quickly lower the needle point on to the soda to make good contact. For a few moments the lamp rheostat does not glow, but soon it does, and then is noted a violent action at the cathode—the soda fuses and little silvery beads rise to the surface of the molten mass. In these few seconds, the solid non-electrolyte has acquired sufficient moisture from the air to give it a conducting coat.

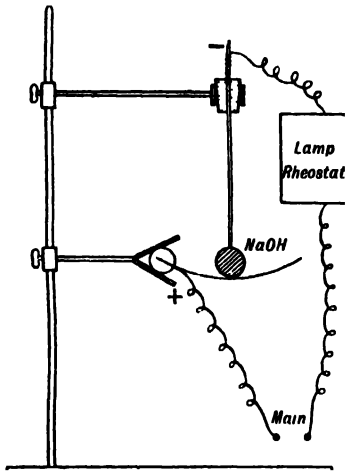


FIG. 188.

Sometimes the little globules burst into flame, but it is best to switch off the current when a large globule forms. This latter becomes coated with a protective layer of hydroxide, and, on cooling, the lump of soda may be dropped into water, when an evident supply of gas is evolved.

For a class to see the experiment properly, it must be close up to the apparatus, and, as spitting sometimes occurs, it is advisable to place a glass screen between the apparatus and the audience.

243. THE EFFICIENCY OF AN ELECTROLYSIS

G. F. Hood

Find the percentage of electrical energy usefully employed in producing sodium hypochlorite when a salt

solution is electrolysed. (Na, Cl, aq) = NaClaq 53,010 cals. 1 calorie = ·24 joule.

An electrolytic cell is improvised by clamping two carbon plates (from old Leclanché cells), properly insulated, in a large beaker which contains a known volume of saturated brine. The plates should be 1–2 cm. apart and a mechanical stirrer should be employed. It is not possible to reproduce easily the efficient large-scale apparatus.

The cell, standing in a bowl of cold water, is connected in series with an ammeter, a key and a 4-volt battery (a resistance box was found to be unnecessary). A voltmeter should be connected in parallel with this circuit. The experiment may be run for thirty to forty-five minutes. The E.M.F. and current should be read every five minutes and average values taken. A measured volume (50 c.c. at least) of the solution is then dropped into excess of potassium iodide solution, acidified with acetic acid, and titrated with decinormal thiosulphate to determine the amount of hypochlorite formed; from this is calculated the amount of salt that has been decomposed *to form hypochlorite.*

The following example is an actual experiment:

Total volume of salt solution = 800 c.c.

Time, 30 mins. E.M.F., 3·9 volts. Current, ·7 amp.

50 c.c. of the solution required 5·60 c.c. of $\frac{N}{10}$ thiosulphate.

Total energy used = E × C × T × ·24 cals.

$$= 3{\cdot}9 \times {\cdot}7 \times 1800 \times {\cdot}24.$$

1 c.c. thiosulphate = ·00355 gram chlorine, coming from ·00585 gram NaCl.

Energy required for the decomposition of the above amount of NaCl is therefore

$$\frac{5{\cdot}6 \times 16 \times {\cdot}00585 \times 53010}{58{\cdot}5} \text{ cals.}$$

$$\text{Efficiency} = \frac{\text{Energy theoretically required}}{\text{Energy paid for}}$$

$$= \frac{5{\cdot}6 \times 16 \times {\cdot}00585 \times 53010}{58{\cdot}5 \times 3{\cdot}9 \times {\cdot}7 \times 1800 \times {\cdot}24}$$

$$= {\cdot}403, \text{ or } 40{\cdot}3 \text{ per cent.}$$

Another experiment with a different stirrer and a higher current density gave 65 per cent.

The student should be required to give some idea as to what becomes of the rest of the electrical energy.

EQUIVALENT RATIOS

244. COMPOSITION BY WEIGHT OF REDUCIBLE OXIDES

D. Ll. Hammick

A small hole is blown in the side of a narrow test-tube ($\frac{1}{4}$-$\frac{5}{8}$ in.) near the closed end. This is conveniently done by closing the tube with a cork or the finger and heating with a small blowpipe jet.

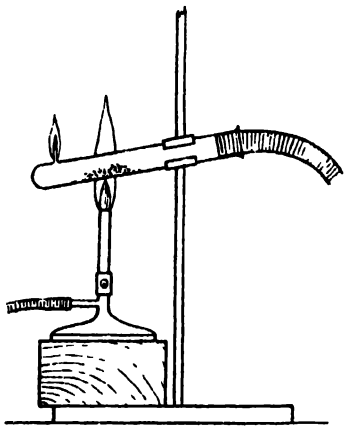


Fig. 189.

A quantity (3–4 grams) of dried oxide is placed in the weighed tube, which is kept on its side, the upper part wiped out and the whole reweighed. The tube is connected to the gas supply by pushing the end of the ordinary gas tubing into the open end of the tube, which is then heated in the Bunsen flame until the oxide is reduced, gas flowing through and burning at the small hole. During this operation, the tube may be held in the hand or mounted on a retort

stand. After cooling in the gas stream, the tube is reweighed and reheated to constant weight.

The following series of values for the equivalent of copper were obtained by a set of 12 boys working in pairs :

32·2	30·1
31·2	31·2[1]
32·0	31·7
32·4	31·1
31·6	30·4
30·1	32·8

Average = 31·4
Standard Value = 31·8 (O = 16).

Good values for the lead oxides can be obtained if the oxide is placed in the tube on a strip of copper foil. Thus, for the percentage of oxygen in a specimen of litharge, the following results were obtained :

7·3	7·5
7·4	7·3
7·5	[8·9]
7·5	7·4
7·6	7·5

Average = 7·4 per cent.
Calculated = 7·2 per cent.

245. EQUIVALENT WEIGHT OF COPPER, ETC.

R. G. Durrant

Counterpoise a dry test tube and plug of glass wool, weigh in it about a gram of pure copper. Add nitric acid and place plug in the open end of tube. Evaporate at sloping angle with agitation till only black oxide remains. Weigh when cool.

Tin and zinc may be dealt with in the same way. A good English-made test-tube will withstand this treatment without breaking. The flame used in evaporation should be 1–2 in. long and just not luminous.

[1] Second attempt.

246. COMPOSITION OF WATER BY WEIGHT

W. Barker

Prepare hydrogen in a Woulff's bottle, from zinc and dilute sulphuric acid, and use agents for purifying it. Weigh the combustion tube (Fig. 190), containing a known weight of black copper oxide wire (previously heated in a current of oxygen). Weigh also a U-tube, containing calcium chloride, for collecting the water formed during the experiment, and attach it to the combustion tube after clip 2, surrounding it by a freezing mixture. The trough containing water is necessary only at the beginning

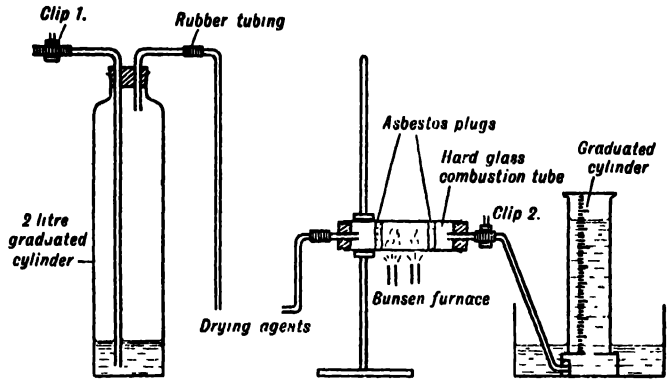


FIG. 190.

of the experiment. Place about 200 c.c. of water in the tall graduated cylinder, and when all parts are connected, open clip 1 and connect up to the hydrogen generator. Flush the whole apparatus for several minutes with hydrogen gas until, on testing, after passing through the water in the trough, it burns quietly. The trough of water may now be taken away. Close clip 1 and clip 2 almost simultaneously, and disconnect the hydrogen generator. Now join the rubber tube holding clip 1 to the water main by rubber and glass connection tubing, being careful to have water right up to the clip. Begin by heating the combustion tube gently and afterwards

strongly. Take the exact reading of the water level in the graduated jar. When the copper oxide is red hot, open both clips and turn on the water gently, allowing a slow current to pass into the graduated cylinder. Hydrogen is thus slowly passed through the combustion tube. When the water reaches the upper limit of the graduation marks in the cylinder, close clip 2, after turning off the water; take away the Bunsen furnace, thus allowing the apparatus to cool. After cooling, reweigh the combustion tube and the U-tube, and take the temperature and pressure of the atmosphere. Care must be taken to drive all the water formed into the calcium chloride tube.

A typical experiment gave the ratio of oxygen to hydrogen as 7·80 : 1. The weight of a litre of hydrogen at N.T.P. can be deduced; in the experiment quoted, this was ·091 gram.

247. COMPOSITION BY WEIGHT OF CARBON DIOXIDE AND EQUIVALENT WEIGHT OF CARBON

W. Barker

The following experiment depends upon the conversion of carbon into carbon monoxide and then into carbon dioxide.

Carbon dioxide is generated in a flask fitted with a tap funnel. The flask contains washing soda, and the tap funnel contains sulphuric acid. A slow current of carbon dioxide can thus be generated and regulated. The gas is dried by passing through drying agents and then carried into the rest of the apparatus. This consists of two combustion tubes, one containing carbon free from hydrogen between two plugs of asbestos, the other containing black copper oxide wire between plugs of asbestos. Both the tubes are carefully weighed at the beginning of the experiment, after having been flushed with dry carbon dioxide (this gas is left in the apparatus at the end of the

experiment). Dry carbon dioxide is passed slowly through the tubes for a short time, after which they are gradually brought to a red heat by means of a Bunsen furnace. The current of gas is allowed to pass now for a considerable time, very slowly, after which the Bunsen

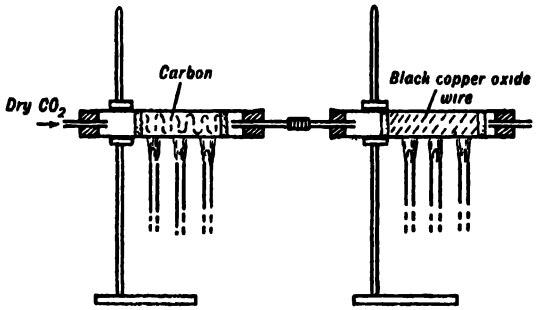


FIG. 101.

furnaces are withdrawn and the tubes allowed to cool in a current of carbon dioxide. They are then reweighed. The two series of weighings give a loss of weight of carbon used up and of oxygen which has combined with it to make carbon dioxide. The calculation can then easily be made. The reactions may be illustrated thus :

First tube. $C + CO_2 \longrightarrow CO + CO$
(from the carbon) (from the gas)

Second tube. $CO + CuO \longrightarrow Cu + CO_2$
(from the carbon)

$CO + CuO \longrightarrow Cu + CO_2$
(from the gas)

248. EQUIVALENT WEIGHTS REFERRED TO CHLORINE

E. J. Williams

Weigh accurately about 5 grams of mercuric chloride into a previously weighed 100-c.c. beaker. Heat on a

water bath with about 30 c.c. of water, and add about 5–10 c.c. of hypophosphorous acid. The mercuric chloride is soon reduced to the metal, which, on further heating, collects into one or more large globules. When this stage has been reached, the metal is washed by decantation with water, alcohol and ether in succession (the last few drops of each can be sucked up by filter paper). Dry for five minutes in the steam oven, cool and weigh.

Good results are readily obtained.

GAS ANALYSIS

249. BURETTE USED FOR SIMPLE GAS ANALYSIS

G. Fowles

The apparatus consists of an absorption cup which is introduced into the burette and held in position by a rubber stopper. A piece of tubing, about 1½ in. long and of bore slightly smaller than that of the burette, is closed at one end and sealed to a short length of glass rod, which carries the rubber stopper. The burette is clamped in position over a trough of water and almost filled with the gas to be analysed. The absorbing material in solid form is placed in the cup, any remaining space is filled with water, the cup closed with the thumb, passed under the water and fixed in position in the burette. After the necessary agitation, cooling, levelling and measuring, a second absorbing material may be introduced. The volume of the burette between the tap and the last graduation mark must be found.



FIG. 192

With this apparatus, a class of junior boys can solve rapidly, and with a satisfactory accuracy, problems involving gas analysis such as :

(1) The amount of oxygen in the air; use pyrogallol and caustic potash; buy compact crystals of pyrogallol, not the voluminous sublimed product.

(2) The carbon dioxide and oxygen in respired air.

(3) The oxygen and carbon dioxide in the gases boiled out of tap water; in this case the product of several workers is united and analysed.

(4) The ratio of carbon monoxide to carbon dioxide in the gas obtained by the decomposition of oxalic acid.

250. GAS ANALYSIS

A. Sutcliffe

By the use of the following simple and easily made apparatus (suggested by a former student, Mr. T. F. Legge), accurate analyses of gases can be performed.

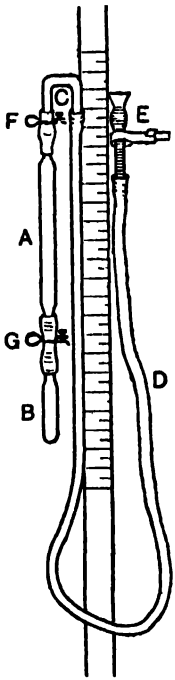


FIG. 193.

In the diagram, A is a piece of glass tubing of about ½ in. diameter, drawn out at each end. B is a smaller piece, about 2 in. long, sealed at one end and drawn out at the other. The drawn-out ends should not be much less than a ¼ in. internal diameter. The smaller tube is fastened to one end of A by means of rubber tubing, fitted with a screw clip, G. The other end of A is similarly fastened to a piece of capillary tubing, which in turn is connected by the pressure tube, D, to a reservoir, E. A mark, C, is made with a file on the capillary tube.

The tube A is filled by displacement of water with the gas to be analysed, the clip F being closed. Tube B is *completely* filled with the absorbing agent and is placed in position, the rubber tube being nipped to expel air. Mercury or water should be used in the pressure tube. The clip F is opened and the reservoir,

E, adjusted until the level of the liquid is at C. The difference in level between the surfaces at E and C is read. The clip F is tightened and that at G opened, and the absorbing agent allowed to flow into A. Tube A is now well shaken (it is not disconnected), and after a few minutes, the absorbing agent is allowed to flow back into B, when the screw clip G is tightened. Clip F is now opened, care being taken that the manometric liquid does not suck back into A. The volume of gas in A is now brought back to its original volume by adjusting the reservoir, E, so that the manometric liquid again reaches the mark C. The difference in level between E and C is again read. The absorption is repeated until two consecutive readings at E are alike.

Corrections may be made for the vapour pressure of the manometric liquid and also for capillary action at C (the latter by noting the difference in level at C and E with both clips open).

The following analyses may be carried out :

1. Determine the percentage of oxygen in air. Use alkaline pyrogallol as absorbing agent and mercury as manometric liquid.

2. Determine the percentage of carbon dioxide in coal gas, using potash as absorbing agent and water as manometric liquid.

3. An analysis of coal gas, using potash, bromine water and cuprous chloride.

251. THE VOLUMETRIC AND GRAVIMETRIC COMPOSITION OF THE AIR

W. Barker

Inside the combustion tube (Fig. 190, p. 32), place between two plugs of asbestos a quantity of copper wire, freshly reduced from black copper oxide wire by means of hydrogen. Weigh the combustion tube and its contents, and use suitable drying agents for drying the air. When all is connected up, with both clips open, pass water into

the tall graduated jar until it reaches the level 200 c.c. Close clip 2 and place the inverted graduated jar full of water over the beehive shelf in the trough of water. Begin heating the combustion tube, and as soon as the copper is red hot, open clip 2 and turn on the water gently, allowing a slow current to enter the jar. When the upper graduation mark is reached, the water is turned off and clip 2 is again closed. Allow the apparatus to cool. Reweigh the combustion tube and its contents. Measure the volume of gas (atmospheric nitrogen) in the inverted cylinder at atmospheric pressure. Take the temperature and pressure of the atmosphere.

Since the weight of oxygen and the volume of nitrogen are measured, the ratio of oxygen to nitrogen by volume or by weight can be found. A typical result gave volume of oxygen : volume of nitrogen, 1 : 3·87.

GASES (DENSITY)

252. WEIGHT OF ONE LITRE OF HYDROGEN

W. Barker

The apparatus (Fig. 194) consists of a hard glass combustion tube, tapering at one end, fixed in two retort stands.

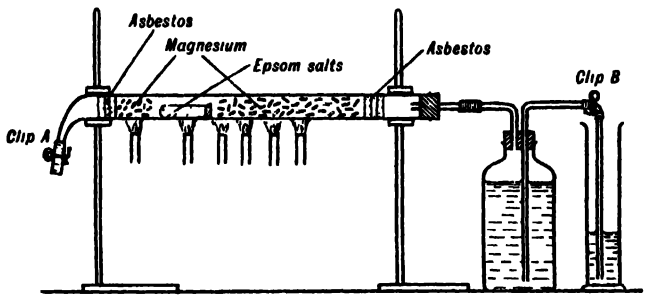


FIG. 194.

At the tapered end is fixed a short piece of rubber tubing, carrying clip A. A loose plug of dry asbestos wool is placed near the tapered end. Beyond this lies about

1 gram of magnesium ribbon, cut into V-shaped pieces. Farther on there is a small test-tube containing about 1 gram of Epsom salts, the mouth being plugged with dry asbestos wool. The remainder of the tube contains about 2 grams of magnesium, cut up similarly to the other. A good rubber cork, carrying a delivery tube, closes up the combustion tube. The rest of the apparatus is the usual Winchester quart bottle and graduated litre jar.

The small test-tube is weighed empty and then re-weighed with the Epsom salts. The tube is then packed as shown.

Open clips A and B and draw air through the syphon tube until this tube is filled with water. When full, close clip B. Fill the graduated jar with water. Open clip B again until the levels of water in the jar and bottle are the same. Close both clips. Empty the water out of the graduated jar and replace under syphon tube. Open clip B.

Begin heating gradually under both sections of magnesium until both are very hot. Gradually heat the tube under the Epsom salts. Steam is given off which oxidises the magnesium and liberates hydrogen. When no more water is carried over into the measuring jar, allow the tube to cool. When cool, adjust the levels in the jar or bottle and close clip B.

Measure the volume of water in the measuring jar.

This is the volume of hydrogen liberated from the water in the Epsom salts. The pressure and temperature of the atmosphere are registered.

A typical experiment gave ·087 for the weight of 1 litre of hydrogen at N.T.P. The time required is about one hour.

253. DENSITY OF CARBON DIOXIDE

P. Graham Gow

A method which has the merits of being both accurate and quick can easily be carried out by making use of a

Sparklet syphon, " C " size, in conjunction with the usual type of apparatus for measurement of volume of gas by water displacement.

The syphon is used without containing any water.

The bulb containing the liquid carbon dioxide is weighed, placed in the holder and pierced. The carbon dioxide vaporises and passes into the syphon, whence it can then be delivered at regulated pace by pressing the lever. The volume of gas is measured by the volume of water displaced from a 6-litre bottle instead of the usual Winchester quart. An oil film on the water in this bottle can be used with advantage. The empty bulb is re-weighed, the loss giving the weight of the carbon dioxide. Typical result :

Weight of bulb full	= 31·52 grams
Weight of bulb empty	= 22·82 grams
Weight of carbon dioxide	= 8·70 grams
Volume of carbon dioxide	= 4,820 c.c.
Temperature of displaced water	= 17° C.
Barometer	= 751 mm.

These values lead to

Weight of 22·4 litres at N.T.P. = 44·3 grams.

GASES (DIFFUSION AND EFFUSION)

254. THE DIFFUSIOMETER

W. Barker

This instrument is a tube of special porous material enclosed in a glass jacket, which is provided with an inlet,

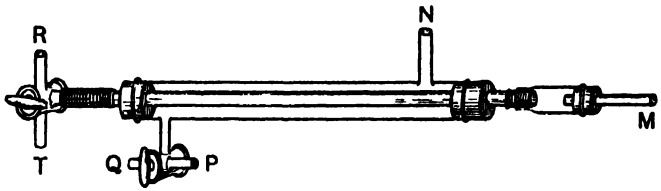


FIG. 195.

N, and outlets, P, Q, controlled, if desired, by a three-way tap. One end of the porous tube has an inlet, M and at the other end there is a three-way tap, if desired, with outlets, T, R.

To show that a Light Gas diffuses more rapidly than a Heavy Gas and to verify Graham's Law of Diffusion

Connect the porous tube to a syphon of liquid sulphur dioxide, and inlet M to a hydrogen apparatus (the gas must be dried). Connect R or T to a conical flask containing an absorbent (concentrated caustic soda solution), for absorbing the sulphur dioxide, and from this flask pass a delivery tube under a beehive shelf in a trough of water. Over the beehive shelf place a graduated jar (in c.c.). Collect the diffused hydrogen through a period of one minute and measure its volume. Repeat the same experiment, using oxygen gas in place of hydrogen. It will be noticed that hydrogen diffuses much more rapidly than oxygen. Compare the volumes of the diffused gas, and see if they are in the inverse ratio to the square roots of the densities.

To find the Density of Coal Gas

Repeat, using coal gas in place of oxygen, and find the respective volumes of hydrogen and coal gas diffused over a period of one minute.

To find the Molecular Weight of Hydrochloric Acid Gas

Connect M to apparatus for generating dry hydrochloric acid gas. Connect N to oxygen cylinder. Connect R or T to a conical flask containing concentrated caustic soda solution, from which passes delivery tubing under a beehive shelf in a trough of water. Over the beehive shelf stand an inverted graduated jar full of water. Connect P or Q to a Volhard trap arrangement

(two conical flasks will do), containing a definite volume of standard alkali solution. Allow the gases to pass through the apparatus over the same period of time, collecting about 200 to 300 c.c. of oxygen. This is done by using the three-way taps, opening them in the proper direction simultaneously, and closing them in a similar manner. Measure the diffused oxygen and, by titration, calculate the weight of alkali still left in the Volhard trap arrangements. From this calculate the weight of diffused hydrochloric acid, and also its volume at the temperature and pressure of the laboratory. Compare the rates of diffusion and thus, from the formula, find the V.D. of hydrochloric acid, assuming that for oxygen to be 16.

In a typical experiment 275·3 c.c. of hydrogen chloride diffused in the same time as 300 c.c. of oxygen. This gives 19 for the density of hydrogen chloride.

For other experiments see the original note, *S.S.R.*, No. 34, p. 116.

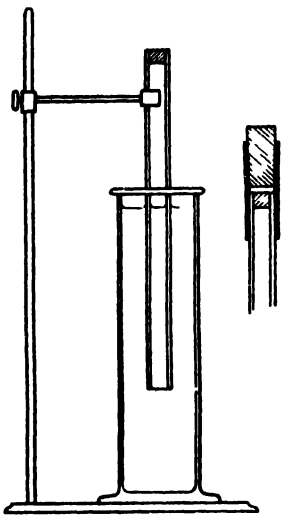


FIG. 196.

255. RATES OF DIFFUSION

B. H. Walmsley

A "diffusiometer" is made by placing a plug of plaster of Paris in one end of a glass tube, about 1 cm. in bore and about 20 to 30 cm. long. The plaster of Paris may be made from ordinary stock calcium sulphate, $CaSO_4 . 2H_2O$, by heating for some time at a temperature of 130° C. in an air oven, stirring the powder occasionally until quite dry. Some of it is then made into a stiff paste with sufficient

water, and a plug of about 5 to 8 mm. thick can then be inserted into the tube. This can be dried in the oven, or by leaving in a dry place for a day or two, when it will have set hard, without cracks.

To use it, a gas-tight cap for the plugged end is made by corking one end of a piece of 8-mm. rubber tubing, about 3 cm. long; this is then fitted. The tube is now filled with hydrogen carefully by displacement of the air. It is placed with the open end just submerged in a deep jar of water, and supported firmly by the clamp of a retort

DENSITY OF COAL GAS BY DIFFUSION INTO AIR

Length of tube filled with coal gas	Length of air column	Ratio of speeds
21·0	15·0	1·40
22·9	15·3	1·49
21·9	14·0	1·56
21·6	14·8	1·46
24·2	15·6	1·55
21·5	14·0	1·53
21·7	14·6	1·48
22·1	15·2	1·45
22·5	15·8	1·42
21·4	15·0	1·43
25·4	17·6	1·45
21·8	15·6	1·41

stand. The cap may then be removed, and diffusion will begin, the water rising in the tube. As it does so, lower the diffusiometer so as to keep the water in it level with that in the jar. Since it will eventually be submerged to about three-fourths of its length, the tube should be clamped in the top quarter. The lowering should be done as continuously as is feasible until the last centimetre or so. When it is quite certain that the water will rise no farther, it may be assumed that the gas in the tube is air. This air has entered in the same time as the hydrogen has diffused through the pores of the plug. The ratio of the length of the tube occupied originally by hydrogen to that now occupied by air will give the relative rates of diffusion of the gases. Given the relative densities of air and

hydrogen, the result may be used to illustrate Graham's Law with fair approximation.

Average result of above series shows that coal gas diffuses about 1·47 times as fast as air.

$$\text{By Graham's Law, } \frac{\sqrt{\text{Density of coal gas}}}{\sqrt{\text{Density of air}}} = \frac{1}{1{\cdot}47}$$

$$\frac{\text{Density of coal gas}}{\text{Density of air}} = \frac{1}{(1{\cdot}47)^2}$$

256. RATES OF DIFFUSION

F. W. Goddard

A glass tube, 50 cm. long, diameter 10–12 mm., has three scratches or rubber bands placed at distances approximately 10, 20, 35 cm. from end A, as indicated by B, C and D.

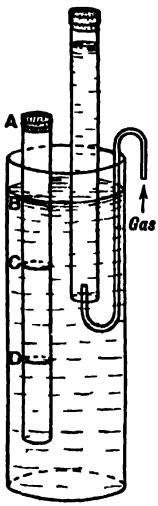


FIG. 197.

At A a small plug of plaster of Paris is inserted and allowed to dry thoroughly. This should be about 5 mm. thick, and must be kept dry. A small rubber cap is required for placing over A to render tube gas-tight when necessary.

The tube is lowered into a tall glass cylinder of water and clamped when sunk to level B. The small cap is removed, and time taken for water level inside the tube to rise from D to C is measured by stop-clock. Several readings are taken.

The tube is now filled as completely as possible with another gas (hydrogen or carbon dioxide). (The small cap is replaced, the tube is raised, and the gas passed in "over water.") Time readings are again taken, with the tube at the same level as before. It is obviously advisable to reject the first reading.

TYPICAL RESULTS OBTAINED BY CLASS OF 16, WORKING IN PAIRS

Time.		Density (H = 1)	Rates of diffusion ratio.	$\frac{1}{\sqrt{\text{Density}}}$
Air:				
6 mins. 40 secs.				
6 ,, 43 ,,	average = 402 secs.	14·4	$\frac{109·5}{402} = 0·27$	$\frac{1}{\sqrt{14·4}} = 0·26$
6 ,, 44 ,,				
6 ,, 44 ,,				
Hydrogen:				
1 min. 52 secs.				
1 ,, 49 ,,	average = 109·5 secs.	1	1	1
1 ,, 48 ,,				
1 ,, 49 ,,				

Oxygen may be used as well as, or instead of, air (there are, of course, certain theoretical but not practical objections to the use of air).

N.B.—Time readings for hydrogen are often relatively rather higher than above, but quite good enough to verify the law.

Rates for carbon dioxide are often faster than for air. This is probably due to its relatively low coefficient of viscosity.

257. EFFUSION OF GASES

Hugh Richardson

First, the class may be employed to prepare the orifices —needle-holes in gas-tight paper. Discs of tracing paper are cut with a cork-borer. Short 5 cm. glass tubes are warmed, touched with paraffin wax, and then the disc is cemented across one end. A hole is bored in the waxed paper with the finest needle.

To measure gas or air passing this orifice, the little glass tube must be attached to some measuring vessel. An inverted burette is convenient when placed in a tall jar of water; a Hempel gas-burette is still more convenient. A volume of, say, 50 c.c. can be marked with gummed

paper, stuck against the measuring scale. Water levels can be arranged so that air may be run either in or out of the orifice, keeping always the same working volume between the same pressure differences. For sharp timing, the race must end before the water comes to rest. A metronome ticking half-seconds supplies the laboratory with time.

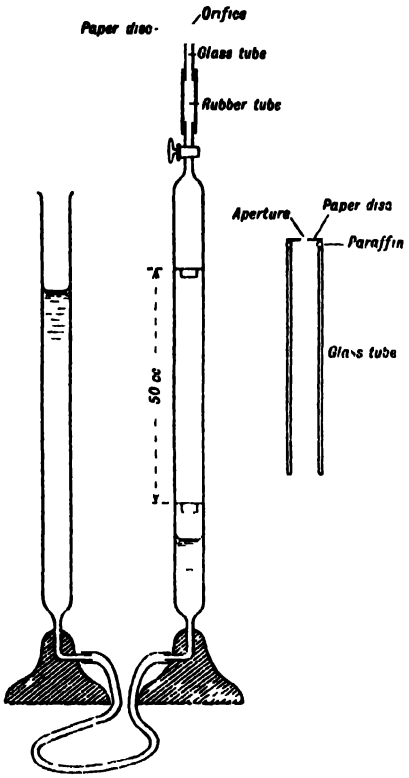


FIG. 198.

Other gases—e.g. coal gas—may be put into the burette. Carbon dioxide is sufficiently insoluble for use over water. The relative velocity of hydrogen to oxygen may be shown to be about four to one.

If the diameter of the needle is measured with a screw micrometer, the area of the orifice can be obtained. Hence a simple calculation shows the velocity of the gas, or the length of gas thread passing the orifice in one second. If we assumed that velocity was proportional to difference of pressure, we might calculate the velocity that the gas thread would have for a difference of 760 mm. mercury pressure, i.e. when gas is diffusing from itself into a vacuum. And this would be the velocity of the molecule according to the kinetic theory.

GASES (GENERAL EXPERIMENTS)

258. ACTION OF NITROGEN PEROXIDE ON WATER

G. H. Martin

Some liquid nitrogen peroxide is prepared in the usual way, by heating lead nitrate and passing the issuing gases through a U-tube in a freezing mixture, the ends of the U-tube then being sealed off. The U-tube is clamped in a vertical position, and one of the drawn-out ends is connected to the bottom of a thistle-funnel by means of a short length of rubber tubing. The shank of the funnel should be of the same diameter as the U-tube.

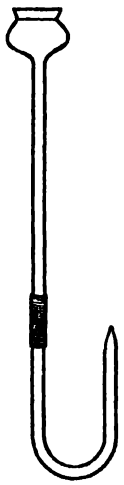


FIG. 199.

The funnel is then filled with water, which is caused to fill the tube of the funnel by alternately compressing and releasing the rubber tube; the funnel may be also filled before being connected with the U-tube. The drawn-out end of the U-tube is then broken with a pair of wire pliers.

On inclining the U-tube so that the liquid nitrogen peroxide can come in contact with the water, brisk effervescence takes place, and a colourless gas rises up the funnel and fills the head of the "thistle" with brown fumes, thus showing that the gas is nitric oxide. The process is repeated until all the liquid oxide has been decomposed, and the changes of colour in the liquid are noted. The contents of the funnel are then transferred to an evaporating dish, neutralised with potash, and evaporated to dryness. The residue, on examination, will be found to consist of potassium nitrite and potassium nitrate.

If the liquid is drawn back into the U-tube during the interaction of the peroxide with water, it can easily be driven out by warming the closed end of the tube.

259. A SEQUENCE OF EXPERIMENTS TO ILLUSTRATE THE LEAD CHAMBER PROCESS

G. Fowles

Reaction of Sulphurous and Nitric Acids

Fill two dry stoppered cylinders (say 100-c.c. capacity) with sulphur dioxide. In one quickly introduce 3–5 c.c. of ordinary concentrated nitric acid, which contains ample water for the action. Nitrogen peroxide forms in quantity, illustrating the production of this gas in the " lead chamber " by the reduction of nitric acid.

In the second cylinder, add only a few drops of nitric acid, and replace the stopper. The brown gas temporarily appears, but soon the walls of the cylinder are covered with crystals of nitrosyl hydrogen sulphate; crystals over an inch long often form. After a time, empty away the gaseous and liquid contents of the cylinder and leave a colourless atmosphere inside. Add a little water; the crystals are then decomposed, with the production of brown gas.

Catalytic Action of Nitrogen Peroxide

Fill a stoppered cylinder with *nitrogen peroxide* and introduce a few c.c. of dilute sulphurous acid. (For a cylinder of capacity 100 c.c, from 3 to 5 c.c. of a half-saturated solution of sulphur dioxide are sufficient—if a large excess of sulphur dioxide is used, the experiment fails.) Replace the stopper and shake; in a minute the brown gas disappears. On removing the stopper a moment, nitrogen peroxide is re-formed, and, on shaking, is again changed to nitric oxide, and so on. Here the nitric oxide takes in oxygen at one end of the cylinder and passes it on to the sulphurous acid at the other.

The experiment illustrates strikingly the catalytic action of the oxides of nitrogen in the lead chamber process, and in conjunction with the following experiments might well replace the familiar large flask with five tubes experiment.

Nitrogen Peroxide and Sulphuric Acid

Fill a stoppered cylinder—such as the 100-c.c. cylinder used in volumetric analysis—with nitrogen peroxide and quickly introduce about 5 c.c. of concentrated sulphuric, acid. On running the acid round the sides of the cylinder, the gas is rapidly decolourised. The effort required to remove the stopper indicates the vacuum in the cylinder, and no " browning " occurs.

The nitrogen peroxide has obviously dissolved in the sulphuric acid.

Pour the " nitrated acid " into a dry test-tube to find its approximate volume, and pour twice this volume of water into a large flask. Next pour the nitrated acid into the water; on gently agitating the flask, the brown gas is instantly evolved, showing its insolubility in 50 per cent. sulphuric acid. The experiment may be repeated and the volume of water varied.

These experiments illustrate the action in the Gay-Lussac tower and one reason for drawing off the chamber acid before it has reached 70 per cent.

260. REACTIONS OF OZONE

L. A. Coxon

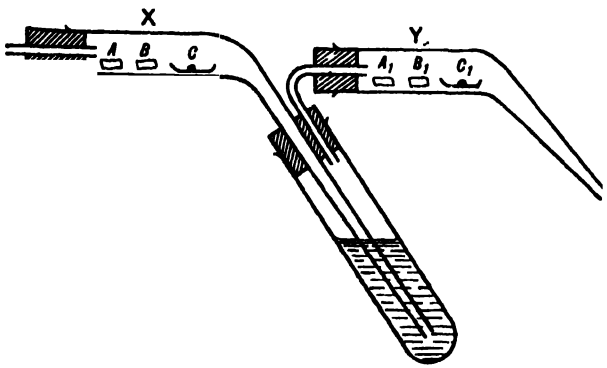


Fig. 200.

X is an adapter, lengthened by fusing on a piece of glass tubing, dipping into turpentine in the 6 × 1-in.

tube. At A, B and C, and at A_1, B_1, C_1, are starch-potassium-iodide paper, lead sulphide on filter paper and a small boat containing a globule of mercury. Ozonised oxygen is passed through the apparatus. Ordinary bark corks are used. The experiment illustrates the chief reactions of ozone and its solubility in turpentine.

261. ACTION OF CHLORINE ON ACETYLENE

Birmingham, 1931

This usually dangerous reaction can be safely shown as follows. About a gram of bleaching powder is placed in a *large boiling tube*, and about 5 c.c. of dilute hydrochloric acid are added. After waiting a few moments till the tube is full of chlorine, a piece of carbide the size of a pea is added. After a short delay, due to chlorine in solution, there is a flash of light ; a cloud of soot and hydrochloric acid gas are formed.

GASES (VOLUMETRIC COMPOSITION)

262. STEAM CONTAINS ITS OWN VOLUME OF HYDROGEN

W. Barker

In place of the combustion tube, Fig. 190, p. 32, use about a foot length of delivery tubing In it place about 2 or 3 grams of dry black copper-oxide wire. This delivery tube passes through a cork fixed into a hole in the side of a large can, which is capable of holding a litre flask well immersed in brine. Fig. 201 explains the rest of the apparatus. The whole apparatus is flushed with hydrogen for several minutes until all air is expelled. The clips are then closed and the hydrogen generator disconnected. The rubber tubing holding clip 1 is now connected to the water main, with the usual precaution. The brine in the can is brought to the boiling point, which should be considerably above 100° C. This is to

prevent the steam from the reaction condensing in the litre flask. When no more bubbles of hydrogen issue from the water in the trough, a graduated jar is placed on the beehive shelf. Heat the black copper oxide; when it is hot, open both clips and turn on the water gently, previously noting the water level in the tall

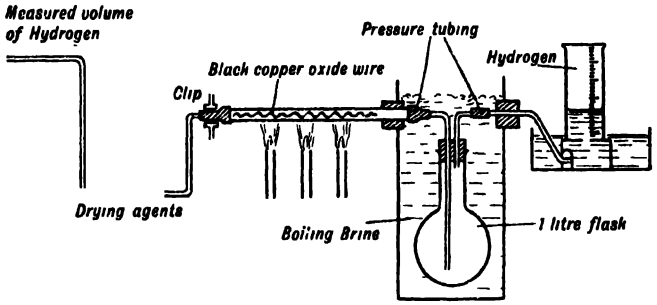


FIG. 201.

graduated cylinder. Hydrogen is slowly passed over the heated copper oxide and steam is produced, which enters the litre flask and, being comparatively heavy, spreads along the bottom of the flask. The volume of steam produced displaces an equal volume of hydrogen, which is collected at the temperature and pressure of the atmosphere. If about 100 c.c. of hydrogen are passed over, 100 c.c. of hydrogen, pushed out by the same volume of steam, are collected in the graduated cylinder over the beehive shelf.

263. ELECTROLYSIS OF HYDROCHLORIC ACID

G. Fowles

By the following procedure, suggested by the late F. E. Weston, equal volumes of hydrogen and chlorine are obtained. Conduct the electrolysis in a calcium chloride tube with side arms; the tube should be filled with concentrated hydrochloric acid to within $\frac{1}{2}$ in. of the side arms. Use carbon electrodes. The current from two

accumulators in series will suffice, but it is preferable to use three or four accumulators. The gases liberated pass through the side arms and are collected over a saturated solution of calcium chloride. It is an advantage to use an all-glass apparatus, of which there are several types. Allow the current to run for twenty minutes before collecting the gases.

264. VOLUME OF HYDROGEN IN HYDROGEN CHLORIDE

G. Fowles

In a lecture experiment to ascertain the volume of hydrogen in hydrogen chloride, after the method originated by Hofmann, the burette cup (see experiment 249), in conjunction with a long tube (say 1–2 ft.), closed at one end, may be used to replace his costly and somewhat cumbersome apparatus. Since 100 c.c. of hydrogen chloride react with 0·1 gram of sodium, the cup will hold sufficient amalgam to provide ample sodium for the reaction; the enormous excess of amalgam used in the original apparatus is unnecessary. After the reaction the burette is opened under water, which avoids contaminating the bulk of the mercury, besides cleansing the sides of the tube, thus allowing the volume to be read without difficulty.

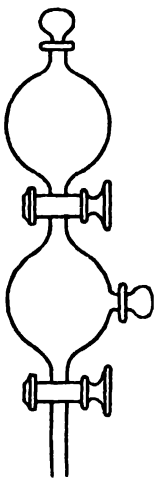


Fig. 202.

265. VOLUME COMPOSITION OF HYDROGEN CHLORIDE

L. L. Garbutt

The stop-cocks are closed and the equal bulbs are respectively filled with hydrogen and chlorine by *displacement* of air. The middle stop-cock is opened and the apparatus hung up in diffused daylight for two or three days. The gases mix by

diffusion and combine to form hydrogen chloride. The tube is dipped into mercury and the lower stop-cock opened; the change of pressure is found to be trivial. Lastly, the tube is dipped into water which fills both bulbs. The apparatus can be modified so that each bulb is used for a separate demonstration.

266. HYDROGEN CHLORIDE CONTAINS HALF ITS OWN VOLUME OF HYDROGEN

W. Barker

Use apparatus similar to that shown in Fig. 204, p. 55. The combustion tube contains asbestos impregnated with silver chloride. This may be prepared by soaking freshly heated asbestos in silver nitrate solution (5 grams dissolved in a few c.c. of water), and then passing HCl gas through a combustion tube containing this asbestos until all the nitrate is changed to chloride, finally heating the combustion tube in a current of the gas until there is no change in weight. The apparatus is flushed with hydrogen at the beginning. Pass 200 c.c. of dry hydrogen through the combustion tube while it is being strongly heated.

267. AMMONIA CONTAINS HALF ITS OWN VOLUME OF NITROGEN

W. Barker

Inside the tall graduated cylinder (see Fig. 190, p. 32), place about 200 c.c. of strong ammonia (sp. gr. ·88) and add powdered litmus to colour it. The combustion tube contains dry black copper oxide and is weighed before connecting up. The apparatus is flushed for several minutes with ammonia gas, prepared by boiling strong ammonia and passing the gas through a soda-lime tower before it enters the graduated cylinder. When the apparatus is completely filled with ammonia, both clips are closed and the ammonia generator is detached. The

level of strong ammonia in the graduated jar is taken. The rubber tube holding clip 1 is connected to the water main, taking the usual precaution. The second graduated cylinder is placed over the beehive shelf in the trough of water. The combustion tube is now heated gently and then strongly, and when it is red hot, both clips are opened and the water tap is turned on gently, thus allowing a slow current of water to enter the graduated jar. When the strong ammonia, now floating above the water in the jar, has reached the upper limit of the graduation marks, the water is turned off and both clips are closed. The Bunsen furnace is taken away, and the combustion tube and its contents reweighed when cool. The volume of nitrogen collected is measured at atmospheric pressure. The temperature and pressure of the atmosphere are recorded.

In an experiment, the corresponding volumes of ammonia and nitrogen were 1,800 and 890 c.c. respectively. From the weight of oxygen used, the corresponding volume of hydrogen can be deduced.

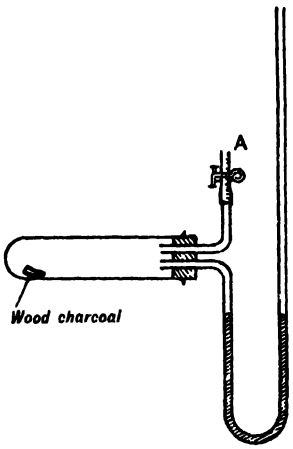


FIG. 203.

268. VOLUME COMPOSITION OF CARBON DIOXIDE

F. Fairbrother

The experiment can be easily performed by means of the simple apparatus shown in Fig. 203.

The test-tube is a pyrex tube, about 8 × 1 in. The tube A, fitted with clip, provides a useful means of filling test-tube with oxygen. This is done before putting mercury in the manometer, B. The mercury level in B is easily adjusted by opening the clip, A. On heating the

charcoal, it is seen to glow in the oxygen and the mercury rises in the right limb of the manometer. On allowing to cool, the mercury returns to the original level and carbon dioxide can be shown to be present in the test-tube.

The apparatus does equally well for the volume composition of sulphur dioxide.

269. CARBON DIOXIDE AND SULPHUR DIOXIDE CONTAIN THEIR OWN VOLUME OF OXYGEN

W. Barker

Inside the combustion tube place about 2 grams of wood charcoal which has previously been heated in a current of dry chlorine in order to free it from hydrogen. After the charcoal, place a roll of oxidised copper wire gauze, to convert any carbon monoxide which may be formed into carbon dioxide. Insert the asbestos plug and weigh the combustion tube. Attach an empty Winchester quart bottle to the end of the combustion tube,

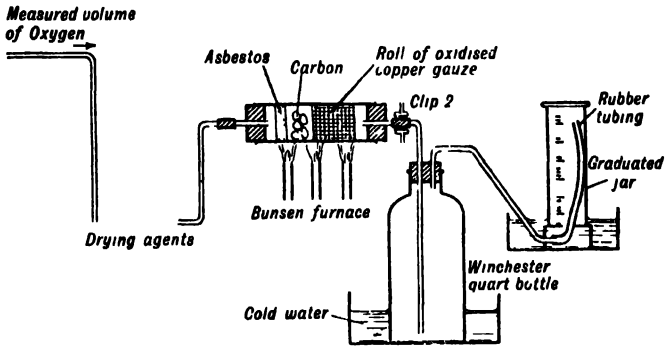


FIG. 204.

as shown in the figure. The tall graduated cylinder contains about 200 c c. of water. When the apparatus is all connected up, flush it with oxygen from an oxygen cylinder or generator for several minutes, until it is full of oxygen gas. Close both clips and connect the rubber tubing holding clip 1 to the water tap, taking the usual precaution. Place the inverted cylinder over the beehive

shelf. Take the reading of the water level in the graduated cylinder. Begin heating the combustion tube, first gently and then strongly, and when it is red hot, open both clips and turn on the water gently. When the upper limit of the graduation marks is reached, turn off the water, close clip 2, and take away the Bunsen furnace. Reweigh the combustion tube and its contents when cool. Measure the volume of oxygen, which has been displaced by an equal volume of carbon dioxide produced in the reaction, at atmospheric pressure.

In a typical experiment, the volume of oxygen passed was 1,800 c.c. and the volume of carbon dioxide produced 1,795 c.c. Also, from the weight of carbon oxidised, the equivalent of carbon was found to be 2·98. The vapour density calculated from the experimental results is 21·9.

In the corresponding experiment with sulphur, no roll of oxidised copper gauze is used. When burning the sulphur, see that none of the vapour condenses in the combustion tube.

270. CARBON MONOXIDE COMBINES WITH OXYGEN TO FORM THE SAME VOLUME OF CARBON DIOXIDE

W. Barker

This experiment is similar to experiment 269. Use freshly made black copper-oxide wire in the combustion tube. Flush the whole apparatus with carbon monoxide instead of oxygen.

Results.—1,800 c.c. oxygen gave 1,787 c.c. of carbon dioxide. Since 1·25 grams of carbon were used, the V.D. of carbon monoxide is shown to be 14.

271. HYDROGEN SULPHIDE CONTAINS ITS OWN VOLUME OF HYDROGEN

W. Barker

Flush the whole apparatus with hydrogen sulphide. Use freshly reduced copper wire in the combustion tube,

The experiment is similar to experiment 269, except that the Winchester quart bottle is not used.

272. NITROUS OXIDE CONTAINS ITS OWN VOLUME OF NITROGEN

W. Barker

Use in the combustion tube freshly reduced black copper-oxide wire. The experiment is similar to those which have gone before.

273. NITRIC OXIDE CONTAINS HALF ITS OWN VOLUME OF NITROGEN

W. Barker

Similar in every respect to experiment 272. Sweep all the air out of the apparatus at the beginning of the experiment by using coal gas or hydrogen, and then flush with nitric oxide.

274. VOLUME COMPOSITION OF NITRIC OXIDE

Cambridge

The right-hand portion of the apparatus (E′, Fig. 205), is used to prepare pure nitric oxide. The bulb, E, is filled with mercury, and a solution of nitric acid in concentrated sulphuric acid is placed in the cup, D. A little of this solution is drawn into E and reacts with the mercury to produce pure, dry nitric oxide, which can be drawn off as required.

The volumetric composition of the nitric oxide is determined in the left-hand portion of the apparatus. B is a glass tube, as shown, provided with a cork at the top, through which passes 2–3 yds. of iron wire, bent into a spiral and reaching to the bottom of the tube. A right-angle bend, with pressure tube and clip, as shown, also passes through the cork. By means of this, the tube can be filled with pure nitric oxide, about two-thirds full, the mercury columns levelled and the positions of the mercury marked on the outside of the tube by a rubber

band. When the nitric oxide has been drawn into B, the apparatus, after F has been tightly closed, can be separated from E. In fitting the cork to B, it should be covered with hot Faraday wax while the pressure inside the tube is lowered. This should be done before filling with nitric oxide. It is also an advantage to draw the iron-wire coil slowly through a Bunsen burner flame before using it.

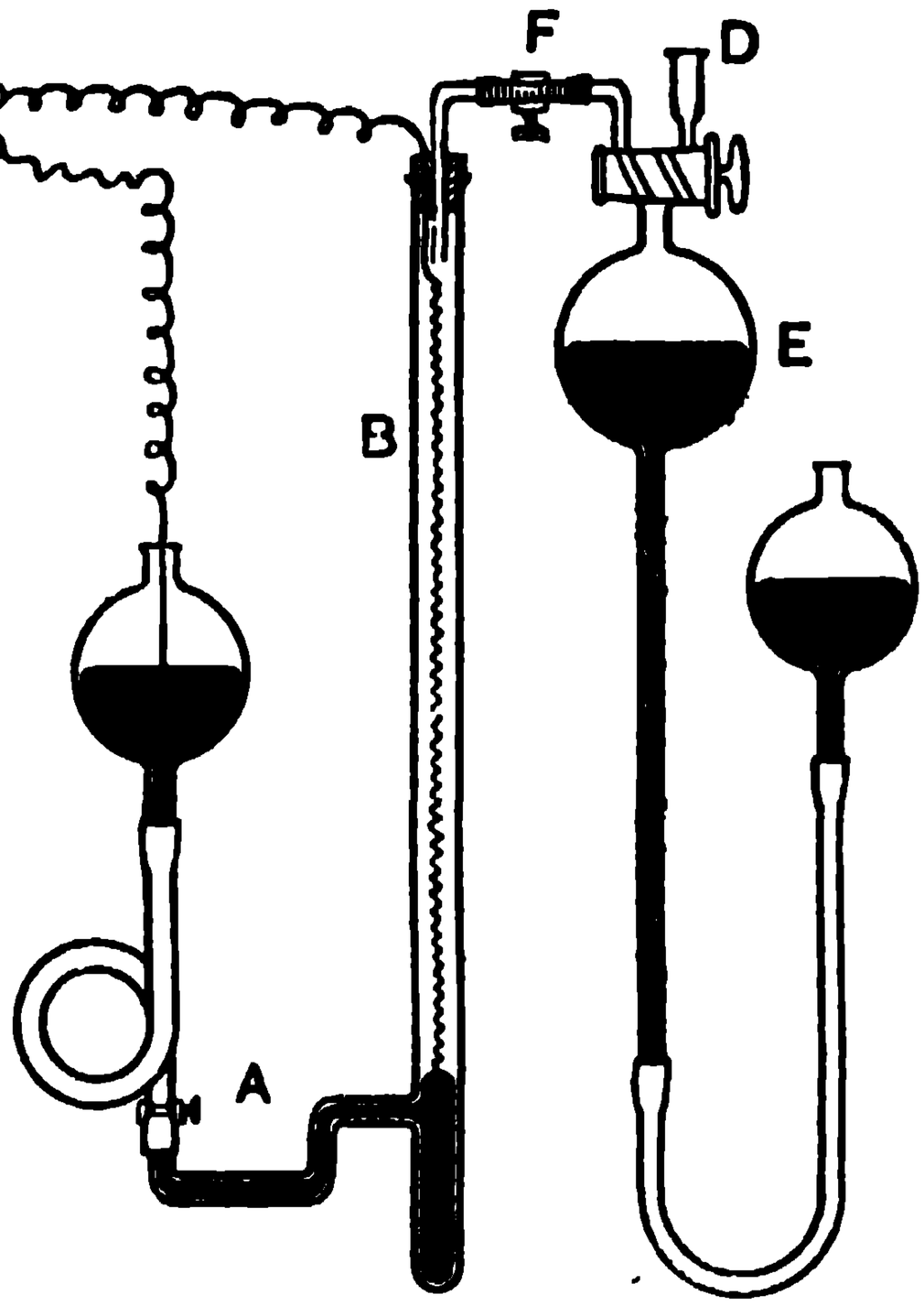


Fig. 205.

When the apparatus is full and the nitric oxide has been measured, the iron wire is slowly heated by connecting to the electric light mains through a suitable rheostat, connection being made through the mercury. The heating should be very slow at first, the temperature of the wire being raised to a dull red heat very slowly and kept at that temperature for about an hour. When no further diminution in volume occurs, the clip, A, is closed (after cutting off the current) until the tube, B, is cool, when the mercury column may be levelled and the volume of nitrogen remaining shown to be one-half of the original nitric oxide.

A new piece of iron wire must be used for each determination.

275. VOLUME COMPOSITION OF SULPHUR TRIOXIDE

Cambridge

At a sufficiently high temperature, sulphur trioxide is decomposed into sulphur dioxide and oxygen. The only

sulphate which gives off sulphur trioxide at a sufficiently high temperature for its complete conversion into sulphur dioxide and oxygen is aluminium sulphate. The most convenient form of this compound is *anhydrous* potash alum.

In the apparatus (Fig. 206), A is a silica or vitreosil tube, containing anhydrous potash alum, connected as shown with a graduated tube filled with mercury. The apparatus is exhausted through the side tube, B, before the experiment is started. On heating A strongly with a Meker burner, sulphur dioxide and oxygen are given off and collect in the graduated tube.

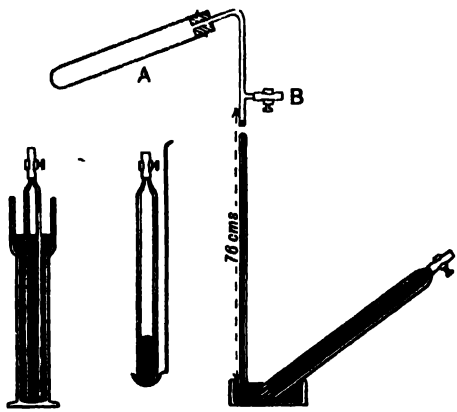


FIG. 206.

When sufficient mixed gases have been collected, the tube is transferred to a vertical mercury trough (a device exactly like a large deflagrating spoon, as shown in the figure, is most useful and more convenient than a small crucible, etc.), levelled and the volumes of mixed gases read off. By means of a bent pipette, a little concentrated caustic soda is then introduced. The volume is again read, and the remaining gas can be shown to be oxygen by holding a glowing splinter over the top when the screw clip is opened.

INDICATORS

276. BUFFER ACTION AND BUFFER MIXTURES

W. R. G. Atkins

The nature of buffer action may best be realised by

making use of salts of weak acids or weak bases and adding to them alkali or acid, in the presence of some appropriate indicator. The same amount of alkali or acid should be added to distilled and to tap water. It will be seen that the indicator changes colour very rapidly in the distilled water, nearly as rapidly in the case of a soft water, rather more slowly with a hard water, and relatively very slowly with one of the salts mentioned.

Use may be made of this slow change to prepare buffer solutions which may serve as standards on account of their stability. As an example, one of the Clark and Lubs buffer mixtures may be chosen, as it is easy to prepare, and covers the range *p*H 5·8–8·0, neutrality being at *p*H 7·0 at 22° C.

For this set of standards two solutions are necessary: first, an M/5 solution of sodium hydroxide. This should be prepared free from carbonate by one of the textbook methods, such as by decantation of a concentrated solution in which the carbonate is insoluble.

The other solution is M/5 with respect to acid potassium phosphate, KH_2PO_4. The salt should be recrystallised and dried to constant weight at 110–115° C. The solution contains 27·232 grams per litre and should be distinctly blue with brom-phenol blue, which shows that it is not too acid, and distinctly red with methyl red, or green with brom-cresol green, which shows that it is not too near neutrality.

The buffer mixtures are prepared as follows. To each of twelve bottles add 50·0 m.l. of the M/5 phosphate and, after addition of the appropriate volume of M/5 sodium hydroxide, the volume is made up to 200 m.l. Below are tabulated the *p*H values of the solutions corresponding to the addition of the sodium hydroxide as shown.

m.l. NaOH	*p*H	m.l. NaOH	*p*H	m.l. NaOH	*p*H
3·66	5·8	17·74	6·6	39·34	7·4
5·64	6·0	23·60	6·8	42·74	7·6
8·55	6·2	29·54	7·0	45·17	7·8
12·60	6·4	34·90	7·2	46·85	8·0

These standard solutions should be kept in well-stop-

pered bottles, preferably of hard glass. Those of *p*H value greater than 7 may best be preserved in bottles coated with paraffin wax inside. If moulds appear in the bottles, they exert very little influence upon the *p*H values, since the buffering is great and the mould can only grow upon the traces of impurity present, since it requires elements other than those used in making up the standards. The addition of a couple of drops of toluene to each bottle acts, however, as a preservative.

For use, 10 m.l. portions may be withdrawn from each of the twelve tubes and run into hard glass test-tubes of about 12–13 mm diameter. To each add 0·5 m.l. of a 0·04 per cent. solution of brom-cresol purple. The first six tubes from *p*H 5·8–6·8 will give a well-marked series of colours. The seventh tube, at *p*H 7·0, should be distinguishable from that at *p*H 6·8 more by intensity than by tint; the others show but little difference from that at *p*H 7·0, not enough to make the indicator useful over the range *p*H 7–8.

To each of another set of twelve tubes add 0·5 m.l. of a 0·04 per cent. solution of brom-thymol blue. This will give a good range of colours between *p*H 6·0 and *p*H 7·4. At each end of the series the tubes will appear rather similar, especially at the alkaline end.

To a third set of tubes, 0·5 m.l. of a 0·02 per cent. solution of phenol red may be added. Here the colour change extends from *p*H 6·6–8·0, which is near the end of the useful range.

It is instructive to plot the *p*H values given in the table against the volumes of sodium hydroxide added.

The effect of diluting the buffer solutions may also be studied. A strongly buffered solution may be diluted considerably without causing an appreciable alteration in the *p*H value.

An attempt should be made to see whether it is possible to distinguish buffer mixtures differing by less than 0·2 units, for example, 0·1, 0·05, 0·02, 0·01. The volume of sodium hydroxide required for buffer mixtures, inter-

mediate in *p*H values between those in the table, may be ascertained from a carefully constructed graph.

The standard tubes may be preserved unaltered for a considerable time if kept with waxed corks or with rubber caps over the ends.

For ranges of acidity or alkalinity beyond those given here, other buffer mixtures and other indicators must be used. Some of the most useful indicators are mentioned in No. 278.

277. ILLUSTRATION OF BUFFER ACTION

Oxford, 1921

In order to show the advantage of standard hydrion solutions over dilute acid, take 50 c.c. of 0·0001 N-hydrochloric acid and 50 c.c. of a solution of the same hydrion concentration prepared as in experiment 279, add a few drops of methyl red to both solutions, and then 1 drop of 0·1N sodium hydroxide solution from a burette. The colour of the indicator in the hydrochloric acid solution will be changed to yellow, while in the acetic acid solution it will be unaffected, and it will be found possible to add half a buretteful of alkali to the acetic acid solution without affecting its colour appreciably, thus showing the reliance that may be placed on these solutions to give a definite hydrion concentration.

278. INDICATORS FOR STUDYING ACIDITY OR ALKALINITY

W. R. G. Atkins

A very large number of substances has been used as indicators. Those most commonly employed in general chemical work twenty years ago were litmus, methyl orange and phenol phthalein. If these are tried with the phosphate buffer mixtures, as described, it will be found that litmus gives a colour change over a wide range, but

the change is not so sharp as with the indicators recommended. Methyl orange, however, changes colour at *p*H 4, so that the buffer mixture tubes will react as alkaline to this indicator. Similarly, all will react as acid to phenol phthalein.

The colour changes of an indicator may be studied as follows. Take two rows of test-tubes, eleven in each. To one set add 10 m.l. of dilute hydrochloric acid, to the other dilute sodium hydroxide. The concentration of acid or alkali is immaterial provided it will just turn the indicator used to its full acid or alkaline colour. (Caution: some indicators, such as thymol blue, have two series of colour ranges.) Starting with the left-hand end of the acid series, add 10 drops of indicator, 9 for the next, and so on, leaving the last tube without any. Similarly, for the alkaline series, 10 drops of indicator are added, but to the right-hand tube. These tubes are then viewed in pairs. That on the left obviously shows the indicator in its full acid colour. The next shows the colour due to 9 drops in the acid condition and 1 in the alkaline. Similarly the other drop ratios may be observed.

The reactions of various solutions may be judged by comparison with indicator tubes; even if one does not know the *p*H value of the tube or pair of tubes, an empirical scale may be constructed.

For judging the reaction of a microscopic object to which an indicator has been added, a device due to Pantin may be used. Those who work with a microscope are familiar with the annoying way in which a window sash or a blind cord may become so focused as to appear in the field beside the object. Accordingly, a set of buffer tubes is made up in small size test tubes and slung from a strip of perforated cardboard near a window. By manipulation of the mirror and condenser, this set of tubes may be brought into the field of view and the cell or tissue under examination may then be roughly matched against the tubes.

Indicators, diluted ready for use or made up as stock solutions, may be obtained from the British Drug Houses, Ltd., Graham Street, City Road, London, N.1, as may also materials for buffer mixtures. Approximate measurements of *p*H values may be made by the aid of the colour chart given by W. M. Clark in *The Determination of Hydrogen Ions* (Williams & Wilkins Co., Baltimore, U.S.A.). The chart may be purchased separately at a dollar a copy, or half a dollar per copy for twenty-five copies. The earlier issues of the chart contained eight colour series, for seven indicators, and the tints were very faithfully reproduced. In the later issues, 1922 and after, ten colour series, for nine indicators, are shown. (Thymol blue is used in the extreme acid and in the extreme alkaline range.) A special effort has been made to get the proper gradation in the tints, but the colours themselves are not nearly as faithful reproductions as are those in the earlier issues. In the third edition (1922) the defects have been to a great extent removed.

In the following table, details concerning the most generally useful indicators are given. The latter are designated by their common or abbreviated names. They are all members of the sulphone phthalein series, save the last.

Indicator.		Concentration, per cent.	Colour Change.	Useful range, *p*H.
Thymol blue,	T.B.	0·04	Red-yellow	1·2–2·8
Brom-phenol blue,	B.P.B.	0·04	Yellow-blue	3·0–4·6
Brom-cresol green,	B.C.G.	0·04	Yellow-green-blue	3·8–5·4
Chlor-phenol red,	C.P.R.	0·02	Yellow-red	5·0–6·6
Brom-cresol purple,	B.C.P.	0·04	Yellow-purple	5·4–6·8
Brom-thymol blue,	B.T.B.	0·04	Yellow-green-blue	6·0–7·4
Phenol red,	P.R.	0·02	Yellow-red	6·6–8·0
Cresol red,	C.R.	0·02	Yellow-red	7·2–8·6
Thymol blue,	T.B.	0·04	Yellow-blue	8·2–9·6
Phenolphthalein, in 95 per cent. alcohol		0·04	Colourless-red	8·3–10·5

279. SOLUTIONS OF DEFINITE HYDRION CONCENTRATION

Oxford, 1921

The theoretical considerations on which the following recipes are based are given in "The Study of Indicators and the Law of Mass Action," by Sir Harold Hartley.[1]

Solutions of hydrion concentration 10^{-3} to 10^{-6} are made by mixing 0·1N acetic acid and 0·1N sodium acetate solutions as shown :

C_H.	Volume. 0·1N acetic acid.	Volume. 0·1N sodium acetate.
10^{-3}	1 litre	18 c.c.
10^{-4}	1 litre	180 c.c.
10^{-5}	555 c.c.	1 litre
10^{-6}	55 c.c.	1 litre

For solutions with hydrion concentration between 10^{-7} and 10^{-11}, the following are required.

(1) A solution of disodium phosphate (Na_2HPO_4), made by dissolving 0·1 gram molecule of the crystalline salt $Na_2PO_4 . 12H_2O$ per litre.

(2) 0·1N hydrochloric acid.

(3) 0·1N sodium hydroxide.

The mixtures are made as follows :

C_H.	Na_2HPO_4 solution.	0·1N HCl.	0·1N NaOH.
10^{-7}	1 litre	322 c.c.	—
10^{-8}	1 litre	47 c.c.	—
10^{-9}	1 litre	5 c.c.	—
10^{-10}	1 litre	—	3·6 c.c.
10^{-11}	1 litre	—	36 c.c.

A convenient method of exhibiting the changes in colour shown by the indicator in solutions of various hydrion concentrations is to arrange three rows of nine 1-in. test-tubes or boiling tubes in a wooden stand, covered with white paper, so that the three rows can be seen simultaneously one above the other, and to place in

[1] *Modern Science Memoirs*, No. 1. Price 1*s*. 4*d*. Obtainable from Rev. Canon Kirkland, Kings' School, Ely.

each tube the same volume of solution according to the following scheme :

c_H =	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}
Top row .	MO	MO*	MO	MO	—	PP	PP*	PP	PP
Second row	MR	MR	MR	MR*	MR	—	TP	TP	TP*
Third row		L	L	L	L*	L	L	—	

* Methyl orange, MO. Phenol Phthalein, PP. Litmus, L. Methyl red, MR. Thymol Phthalein, TP.

A few drops of the indicators are then added as shown above, and the colour changes observed. The asterisks in the table above show the hydrion concentrations at which the transition colours are most marked.

280. THE BJERRUM TANK

Oxford, 1921

A more exact estimate of the hydrion concentrations can be made by means of a simple device due to Bjerrum, which is of much assistance in studying the properties of indicators.

It consists of a rectangular trough, with thin plate-glass sides, which is shown in plan and front and side elevation

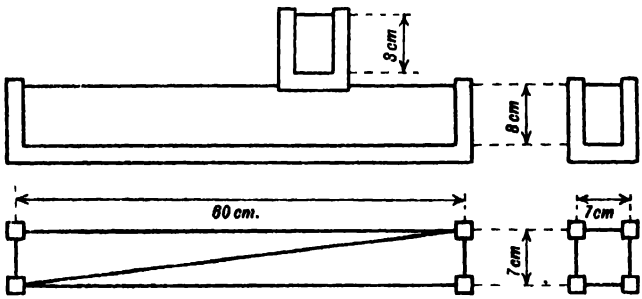


FIG. 207.

in Fig. 207. The glass fits into grooves in the wooden sides and bottom of the trough, and is cemented by means of a mixture of white and red lead and gold size. The trough is divided into two wedge-shaped compartments by a diagonal piece of glass. One compartment is filled

with a solution of the indicator containing acid, and the other with a solution of the same concentration of indicator containing excess of alkali, care being taken to add sufficient acid and alkali to transform the indicator completely.

The front view of the trough will show the whole range of colour of the indicator, from the undissociated to the dissociated form. The colour in the middle of the trough is obviously that shown when the indicator is half transformed.

A cell of the same thickness as the trough is placed vertically above it, so that it can be moved from one end of the trough to the other. If solutions of known hydrion concentrations and with the same indicator concentration as the trough are placed in the cell, and it is moved until the tint shown in the cell is the same as that in the trough vertically below it, an empirical graduation of a scale at the foot of the trough will be obtained, showing the hydrion concentration corresponding to the indicator tint in each part of the trough. Observations must be made against a white background, and they are much facilitated by attaching a piece of white cardboard, with a narrow vertical slit, to the front of the movable cell, so that the colour of the solution in it may be compared more easily with that in the trough vertically below it.

281. PRECIPITATION OF METALS AS HYDROXIDES

W. R. G. Atkins

When an alkali, such as sodium hydroxide, is added to a salt of any of the metals save those in the sixth group of the usual analytical scheme, a hydroxide -or a basic salt—of the metal is precipitated. For each metal there is a definite limit of *p*H values within which it is precipitated. Thus, on addition of indicator to a ferric salt, such as ferric chloride, the reaction will be found to be around *p*H 3, giving a yellow with thymol blue and with

brom-phenol blue. On addition of alkali, a red-brown precipitate appears and the second indicator shows the full blue colour. The solution may thus have all but a trace of ferric iron removed before *p*H 5 has been reached.

Try the same experiment with copper sulphate—what is its region of precipitation ? Try also magnesium sulphate and calcium chloride.

282. RUSTING OF IRON

W. R. G. Atkins

For the rusting of iron, oxygen, water and a trace of acid are required. In the process oxygen is used up, also a certain amount of water, but the acid may be said to act as a catalyst and is regenerated.

As shown before, ferric hydroxide is precipitated at *p*H 3·5–5·5, but ferrous hydroxide comes down from about *p*H 5·1- 7·6. Use brom-phenol blue as indicator to show difference in reaction between ferric and ferrous salt in solution. On standing for some days, the ferrous salt becomes more acid, and a precipitate of ferric hydroxide appears Thus acid is set free when the ferrous salt is oxidised to the ferric condition, because the latter is more strongly hydrolysed. The solution never becomes more acid than does that of a ferric salt.

The action of carbon dioxide in solution can also be demonstrated. Bright iron wire is carefully washed free from the lime in which it is stored, being finally dipped in dilute acetic acid and thoroughly washed with distilled water. It is then placed in a test-tube with distilled water to which brom-thymol blue has been added. The full yellow colour of the indicator denotes the presence of free carbonic acid. To demonstrate the rapidity of the action on iron, one must work near the neutral point; the water is therefore brought to *p*H 6·6–6·8, as shown by the yellowish green colour, by the addition of a trace of a bicarbonate. On standing for a few minutes, the liquid next the wire becomes blue, an intense blue being produced within one

hour; the acid has been consumed by action on the wire, so the liquid reacts as alkaline. On shaking up, the whole tube becomes blue, but on allowing to stand, the green colour reappears in the parts remote from the wire, especially near the surface, owing to the oxidation of the ferrous salt, with regeneration of acid. The changes occurring round the wire may be projected on a screen for lecture purposes.

With solutions which are alkaline at the start, namely, those containing fewer hydrogen ions than does *pure* water, the change proceeds, though more slowly.

Using phenol red, a pink colour may be produced, the colour being yellowish or faintly pink at the start. In time a good red colour may be seen, indicating *p*H8. Thus the minute concentration of hydrogen ions present in the faintly alkaline solution has been reduced by action on the metal, the resulting liquid being still more alkaline. It may thus be seen that the first stage in the rusting of iron is the reaction between the metal and hydrogen ions. This ceases unless oxygen be present; when present, the ferrous salt is oxidised to ferric and acid is set free again. The process accordingly becomes continuous.

In all such experiments with indicators, one of the well-known types of British resistance glass should be used. The writer has used "Monax" and "Duroglass."

283. RESISTANCE GLASS AND SOFT GLASS

W. R. G. Atkins

Superstitions die hard, especially with biologists, who cannot always apply the direct tests possible in a chemical laboratory. These superstitions include the belief that it is necessary to use foreign resistance glass and foreign pure chemicals.

Tests should be made of all glassware used in work on hydrogen ion concentration. It is required that the glass should not yield alkali during the process to which it is

being subjected. This is an ideal which cannot be realised with hot alkaline solutions. The resistant glasses may, however, be distinguished from soft glass or glass of inferior resistance by placing on a boiling water bath for two hours, after filling with tested distilled water. When just cool, add brom-thymol blue, in its neutral (green) state. No blue colour should be produced.

The distilled water, tested before boiling, will probably give a yellow (acid) colour with this indicator. After boiling, owing to the expulsion of carbon dioxide, the water should be neutral.

284. NATURAL WATERS

W. R. G. Atkins

Natural waters may be roughly grouped into those which are soft, namely, very low in calcium salts, or hard, relatively rich in salts of calcium and often magnesium, or salty, containing more than traces of sodium chloride.

The difference between hard and soft waters may be shown by means of indicators, brom-thymol blue being specially useful, also phenol red.

The town supplies of Plymouth, Dublin and Aberystwyth are very soft, and are acid in reaction. In London, Cambridge and very many other towns, the supply is hard, and gives a red with phenol red. But hard water may show a yellow with phenol red if it contains more carbon dioxide than normally exists in such a solution when in equilibrium with the air. Blow gently into a tube of tap water, red with phenol red. The red colour changes to yellow. On vigorous shaking, the excess of carbon dioxide is given off and the red colour is restored.

Test water from a spring. It is probably around *p*H 6, even if in a calcareous district. Shake with air: the water becomes less acid and may become quite alkaline. Try placing a pond weed, such as *Spirogyra*, in such water. The plant uses up carbonic acid and the water becomes alkaline, round the filaments first, then all through.

Water in ponds may for this reason be markedly alkaline, even giving a blue with thymol blue or a good red with phenol phthalein. Moorland water may be markedly acid, *p*H 5–5·5.

Brackish water and sea-water are normally alkaline, around *p*H 8, but in a small aquarium, over-stocked with animals, the water may fall to *p*H 7·6 or lower. In rock pools, in bright light, the plants may make the water strongly alkaline. In tests with sea-water, subtract 0·2 units from the apparent *p*H value for salt error.

285. REACTION OF SOILS

W. R. G. Atkins

Since natural waters come up through or over soils, they indicate in a general way the average soil reaction of a district. To study soil reaction, shake up soil and distilled water in a 1 : 5 proportion, roughly. Soils being strongly buffered, the proportions may be altered within wide limits, as a rule, without producing much alteration in the *p*H value. Add indicators and allow to settle. Judge the colour in the clear liquid. Most likely it will not become quite clear. If so, use the comparator method—pairs of tubes. In front of the standard buffer tube place a tube of the turbid extract, without indicator ; in front of the soil extract with indicator place a tube of distilled water. A better colour match may thus be obtained.

If very turbid, try the colour of spots on a porcelain plate, adding indicator. Use a centrifuge to clear, if available. Do not filter, since this may introduce serious errors. Try spots of indicators on ordinary and ashless filter papers. Note the reaction of the paper. See if washing repeatedly with hot distilled water affects this.

Soils vary widely in reaction, from about *p*H 4 for peaty soils to *p*H 8 for limestone. Note the types of plant found on soils of different reaction. On what soils are snails found abundantly of the same sort, abundantly of different sorts, in small numbers or not at all ?

Are earthworms found in all types of soil; if not, what limits their distribution? Are any insects similarly limited?

286. REACTION OF PLANT TISSUES

W. R. G. Atkins

Cut cross-sections of stems, roots, petioles, leaves, or pound up homogeneous tissues. Add drops of indicators and note approximately the reactions given by the different tissues in the same organ.

287. INFLUENCE OF ACIDITY AND ALKALINITY UPON ENZYME ACTION

W. R. G. Atkins

Take a little malt extract or saliva in a test-tube; add indicators to ascertain reaction. Test rapidity of action on starch solution, noting time required for destruction of all the starch, as shown by failure to obtain blue colour with iodine or purple colour with the dextrin first produced.

Then bring fresh portions of the enzyme-containing liquids to different degrees of acidity or alkalinity by adding hydrochloric acid, acetic acid, the standard buffers at *p*H 6, *p*H 7 and *p*H 8, sodium carbonate and sodium hydroxide. Note the times for destruction, as before.

If a constant temperature bath is available, see whether the optimum *p*H value is the same at 0° (ice bath), room temperature, 15°, 25° and 40°.

IONISATION

288. THE ABNORMALITY OF MERCURY SALTS

R. G. Durrant

Mercuric chloride may be sublimed right through sulphuric acid without appreciable change, though other

chlorides, in like circumstances, produce hydrochloric acid.

Mercuric cyanide hardly ionises at all, and fails to give a scarlet precipitate when mixed with soluble iodides—and mercuric salts in general are slow to deposit mercury on copper without external assistance.

If highly ionised acids, like hydrochloric, are added, the scarlet precipitate, or the deposit on copper, appears rapidly.

289. IONIC VELOCITIES

W. H. Barrett

The tube C in Fig. 208 is 40 cm. long. It is filled with jelly made as follows. Soften 10 grams of gelatine by

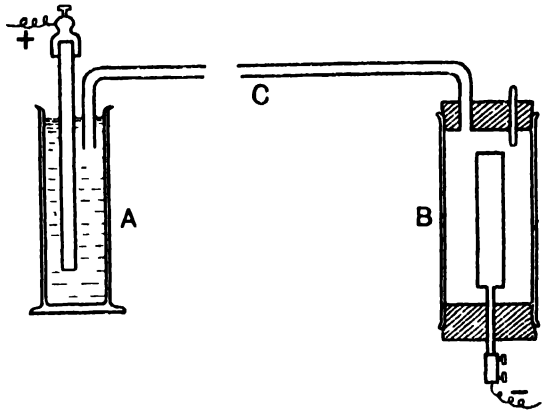


FIG. 208.

allowing it to stand in cold water, pour off the water, add 140 c.c. of water and immerse beaker in warm water till the gelatine is melted, add 7 grams of sodium chloride and colour rose-pink with a few drops of alkaline phenolphthalein. When the jelly has set in the tube, one end is inserted in a jar, A, containing dilute hydrochloric acid and a carbon anode; the other end passes through a cork in the top of the wide tube, B, which is completely filled

through the hole in the upper cork (afterwards closed by a piece of glass rod) with a 10 per cent. solution of nickel chloride, and contains a nickel cathode passing through the lower cork. (A boiling tube may, of course, be used, putting the nickel cathode through the same cork as the tube C and the glass rod.) A copper cathode and copper chloride solution may equally well be employed. On passing a current of electricity (P.D. between electrodes 20–24 volts) $H^{\cdot}$ ions move towards the cathode and Cl' ions towards the anode, decolourising the jelly as they go.

The moving boundaries are beautifully sharp, so that the relative velocities of the $H^{\cdot}$ and Cl' ions may be obtained by direct measurement.

LABORATORY NOTES (MISCELLANEOUS)

290. PRESERVATION OF DIAGRAMS

W. H. Barrett

Ordinary paper varnish, as obtained from one of the large chemical houses, such as Harrington's, and applied to the cardboard, will give a lasting surface. A much better job will be made of it if a coat of celluloid varnish (made by dissolving scrap celluloid, such as old protractors or set squares, in amyl acetate and thinning with acetone) is applied to the cardboard and allowed to set before the varnish is put on.

For making large diagrams, the best material is the continuous cartridge paper, mounted on cloth and sold in rol's, 40 in. wide (4*s*. 6*d*. per yard), by Messrs. Winsor & Newton. Pieces of any suitable size can be cut off the roll for diagrams of varying dimensions. If the diagrams are drawn in Indian ink and the surface is afterwards treated with celluloid varnish and then paper varnish, a first-rate and lasting diagram is obtained. If a strip of wood be fastened to the top and bottom with drawing-pins or large-headed tacks, the diagram can be rolled up and stored conveniently when not required.

291. LABELLING OF LABORATORY REAGENT BOTTLES

G. C. Bachelor

The following method is at once cheap, simple and effective for all ordinary reagents, although, naturally, the labels will be affected after a time by strong acids or caustic alkalies.

The best results are obtained with labels printed (or written) on fairly thin paper. Attach by gum in the usual way, taking particular care that no air bubbles are left under the paper, and allow to dry.

Next melt some paraffin wax in an evaporating dish, heating until a faint smoke just begins to form. Avoid heating beyond this point, or the wax will ignite.

Apply the molten wax to the label with a flat bristle brush. Pass a Bunsen flame *quickly* over the waxed surface, and while the wax is still warm, wipe away any surplus from the glass with a soft cloth, leaving, however, a narrow margin of wax all round the label.

292. TREATMENT OF BENCH TOPS

Alan E. Manby

The best method of preserving the wood tops of laboratory benches is by frequent treatment with raw linseed oil. The surface should first be scrubbed with soap and water and allowed to dry; the oil should then be well rubbed in and allowed to dry thoroughly, after which further applications may be made until the wood will absorb no more. The object of small intermittent applications is to enable the oil to oxidise and thus solidify into a resin; if too much oil is applied at once oxidation is prevented and the surface remains sticky. If necessary, the oil may be thinned with a little turpentine, which will evaporate.

Alternative treatments consist of (*a*) rubbing in beeswax softened with turpentine, or one of the proprietary

floor polishes of like composition; (*b*) ironing in paraffin wax, or rubbing in a solution of the wax in petrol, xylene or other solvent; and (*c*) treatment with aniline black.

Paraffin wax has a low melting point, and unless completely absorbed, becomes a nuisance by melting when hot bodies are placed on the bench. Aniline black, though very resistant to acids, involves almost entire loss of light by reflection and forms a very sombre background for work.

293. LACQUERING BRASS

G. C. Bachelor

For a brass surface that has not to stand a very high degree of heat, treatment with a lacquer made from shellac and methylated spirit will often give a pleasing result. For this, it is first necessary to get the surface thoroughly well cleaned. In many cases this can be accomplished by dipping the article in moderately strong nitric acid (old battery acid is best) until quite bright, washing quickly in running water and drying in an air or steam oven. A screw thread, of course, must never be dipped in this way. If the dipping method is not adopted, the surface may be cleaned with a file, followed by successively finer grades of glass paper, bearing in mind that all file marks must be eliminated, since the lacquer will make these prominent. Whichever method of cleaning is used, the object must not afterwards be touched with the bare fingers, a clean duster or a piece of newspaper being used to handle it.

To prepare the lacquer, fill an 8-oz. wide-mouthed bottle about one-third full of flake shellac, filling up to the top with methylated spirit. Allow to stand for several hours, shaking at intervals, and then leave to settle for twenty-four hours more. At the end of that time, there should be a clear, deep-brown liquid at the top, and a turbid one below. Carefully pour off the former and keep it to use as lacquer. The turbid portion

need not be wasted, for it makes quite good insulating varnish and may be used on woodwork.

The article to be treated should be heated in an oven until warm; it should then be grasped by the edges, or supported by a piece of wood forced into a convenient hole; the lacquer can then be applied with a fairly large, soft camel-hair brush, well charged with the liquid. The brush should be used with a long, light stroke, and care should be taken not to touch any portion of the surface a second time. The covering will dry almost at once, and the resulting surface will present a pleasing appearance, and be proof against most common laboratory fumes and the effect of acids, although liable to be attacked by strong alkalis. By dissolving a little anilin green in the lacquer, the effect frequently seen in purchased apparatus can be quite effectively imitated.

294. A DURABLE FILLING FOR GRADUATION MARKS

G. C. Bachelor

It is difficult to find a really satisfactory composition for this purpose, but the following gives quite good results.

Take a few drops of Indian ink. It must be of the waterproof variety. There is a brand known as "Chin-Chin," which is stickier than the usual kinds, which gives the best results.

Mix this to a cream with a little barium sulphate and rub well into the markings, afterwards wiping with a soft cloth to remove any black from the rest of the stem.

This should be allowed to stand exposed to light for a day or two, when it will be found to resist hot water, alcohol and dilute acids quite well.

Bituminotic paint, which can now be obtained from most oil and colour merchants, is also recommended.

295. RENEWING THE RUBBERS OF FOOT-BLOWERS

S.S.R., (I) 4.

The sheet rubber sold for the purpose is somewhat expensive, and usually the fixing in position is a tiresome process.

It will be found that amongst the discarded school association football material there are, as a rule, several bladders which have "gone" at the base of the neck only, and are otherwise sound. These, if cut round about 3 in. from the neck, will form rubber bags which can be conveniently drawn over the beading of the blower and fixed in position with wire or string. They are found to give very satisfactory results.

296. SENSITIVE PAPER FOR HEAT EXPERIMENTS

E. F. Thompson

The addition of ammonium chloride to the solution of cobalt chloride (the proportion does not seem to matter very much) makes a marked improvement in the sensitiveness of the paper. The solution can be diluted to a pale pink, so that the paper soaked therein is almost colourless. On heating, however, the paper turns to a vivid green.

297. REMOVAL OF INK FROM WOOLLEN CLOTH

J. P. Turner

The following solutions are convenient: oxalic acid, 10 per cent ; ammonium oxalate, a saturated solution ; ammonia solution, ·880.

Ordinary ink, if fresh, is removed by ammonium oxalate solution alone, and old ink stains by ammonium oxalate, followed by ammonia. Copying ink, duplicator ink and red ink (made from powder) are removed by similar treatment.

298. WORKSHOP RECIPES [1]

A. H. Chapman

Notes on Solders

The equipment must include some tinman's solder, chloride of zinc (or Baker's fluid) and fluxite or coralline.

Tinsmith's solder, which is the soft solder used for general purposes, consists of tin 66 per cent., lead 34 per cent.

For electrical work, the tin is sometimes pushed up to 95 per cent.; such solder is more expensive.

For plumbers' "wiped joints," the ratio is lead 66 per cent., tin 34 per cent. This gives a solder which is "pasty" over a range of 60° C. between complete fluidity and complete solidity.

The eutectic ratio (the alloy with the lowest melting point) is lead 37 per cent., tin 63 per cent., with a melting point of 182·5° C.

Notes on Fluxes

Zinc chloride is the easiest to use, but is corrosive and attracts moisture. For zinc or zinc-coated metals use dilute hydrochloric acid.

Resin is an excellent flux for copper, brass, tinned plate, etc. For soldering fine wires in electrical instrument work, use resin dissolved in methylated spirit. Resin is not good for iron and steel. For lead gas pipes, use either resin or tallow or both. "Fluxite" will do. "Fluxite" is an excellent flux for all general purposes, except on zinc. "Coralline Soldering Paste" (made by the British Insulated and Helsby Cable Co., Helsby, near Warrington) is superior to "Fluxite" for electrical work, since it is less corrosive, but the surfaces must be very carefully cleaned before it is applied.

Notes on Brazing

For brazing brass: copper 50 per cent., zinc 50 per cent.

[1] *School Science Review*, (VI) December 22nd, 1924. For fuller treatment of these and other laboratory workshop methods, see *Workshop Practice for the School and Laboratory*, by A. W. Barker and A. H. Chapman. Sidgwick & Jackson 3*s* 6*d*.

For brazing copper: copper 52 per cent., zinc 48 per cent.

For brazing steel: copper 55 per cent., zinc 45 per cent.

The 50/50 is necessary to get a low melting point when dealing with brass. Sometimes 1 per cent. tin is added.

Silver solder: hard, silver 4 parts, copper 1 part; easy flowing, silver 2 parts, brass wire 1 part.

For brazing and silver soldering, use moist powdered borax as flux.

Aluminium solder: tin 92 per cent., zinc 8 per cent. Clean the aluminium carefully by scraping, and use an aluminium soldering iron coated with the solder.

Notes on the Silvering of Mirrors

A solution of pure crystallised nitrate of silver in distilled water is made up to a strength of 125 grams of the salt per litre. This forms the stock solution and is kept in a dark bottle.

Let the volume of the silvering liquor required in any operation be denoted by 4V. The liquor is prepared as follows:

(1) Measure out a volume, V, of the stock solution of silver nitrate and calculate the weight of the salt which it contains; let this be w. In another vessel dissolve pure Rochelle salt to the amount of $2{\cdot}6\ w$ and make up the solution to the volume V. These two solutions are to be mixed together at a temperature of 55° C., the vessels with their contents being heated to this temperature on the water bath.

After mixing the liquids, the temperature is to be kept approximately constant for five minutes, after which the liquor may be cooled. The white precipitate which first forms will become grey or black, and very dense as the liquid cools. If it does not, the liquor must be reheated to 55° C. and kept at that temperature for a few minutes and then again allowed to cool. The solution is in good

order when all the precipitate is dense and grey or black and the liquor clear. The blacker and denser the precipitate, the better is the solution. The liquor is decanted and filtered, and brought up to the volume 2V by the addition of some of the wash water.

(2) Measure a volume 0·118V of the stock solution into a separate vessel and add to it a 5 per cent. solution of ammonium hydrate, with proper precautions, so that the precipitate at first formed is all but redissolved after vigorous shaking. It is very important that this condition should be exactly attained. Therefore add the latter part of ammonia very carefully. Make up the volume to 2V.

Mix the solutions (1) and (2) in a separate vessel and pour the mixture into the depositing vessel. The surface to be silvered should be face downwards and lie just beneath the free surface of the liquid. Bubbles, of course, must be removed.

The silver deposit obtained in this manner is exceedingly white and bright on the surface next to the glass, but the back is matt and requires polishing.

Useful Recipes for the Laboratory and Workshop

Faraday Wax (red).—Resin, 5 parts ; beeswax, 1 part ; red ochre (finely powdered), 1 part.

Sealing-wax (black).—Shellac, 5 parts ; turpentine, 9 parts ; resin, 6½ parts , chalk, 4 parts ; lamp-black, 1 part.

Chatterton's Compound (flexible) —Resin, pitch and gutta-percha This can be bought in ¼-lb. sticks.

Cements

Waterglass and Lime Cement —Quick-lime, 10 parts ; whitening. 100 parts ; waterglass, 25 parts.

Waterglass and Portland Cement - Equal parts of each.

Cement for Iron.—Iron or steel filings, 16 parts; sal-ammoniac, 3 parts; flour of sulphur, 2 parts. Take 1 part of this mixture and 12 more of iron filings, and mix with water acidulated with sulphuric acid to a paste.

Acid Proof (plastic).—A solution of india-rubber in twice its weight of raw linseed oil, heated and mixed with an equal weight of pipe-clay.

Quick-lime and linseed-oil, mixed stiffly together, form a hard cement resisting both heat and acids.

Pipe-clay and coal tar mixed together also make a good useful cement.

A concentrated solution of silicate of soda, formed into a paste with powdered glass, is useful where a luting is required to resist the action of acid fumes.

One part of resin, 1 part of sulphur, 2 parts of brick-dust, carefully mixed and melted, is proof against nitric and hydrochloric acid vapours.

Dips

Bright Dip for Brass.—Sulphuric acid, 10 parts; nitric acid, 5 parts; water, 5 parts.

Matt, or Dead Dip for Brass.—Sulphuric acid, 2 pints; nitric acid, 2 pints; metallic zinc, 1½ oz. Dissolve the zinc in the nitric acid first.

Bronze and Black

Steel Bronze for Brass.—One part oxide of iron, 1 part white arsenic, 12 parts hydrochloric acid.

Optical, or Dead Black.—Lamp-black mixed with gold size to a paste, adding turpentine to the thinness required. "Blacquett" can be purchased both brilliant and dull; it is made by the Castle Brand Co., Newcastle-on-Tyne.

Lacquers

Common lacquer consists of shellac and methylated spirit, approximately ½ lb. of shellac to 1 gallon of spirit. The mixture should be agitated occasionally and,

when dissolved, the clear part should be filtered, and colouring matter can then be added.

A good lacquer for instrument work is "Seed-lack," 6 oz.; dragon's blood, 40 grams; amber and copal triturated in a mortar, 2 oz, extract of red sanders, ½ dram; oriental saffron, 36 grams, powdered glass, 4 oz; absolute alcohol, 40 oz

Messrs Gedge & Co, 88 St John Street, Clerkenwell, E.C., supply all good qualities Colourless, pale gold and telegraph are the three kinds recommended for general purposes. Optical-black, or dead black, can also be obtained from them.

MULTIPLE RATIOS

299. CHLORIDES OF COPPER

G. H. Benham

Weigh about 0·8 gram of copper, previously cut into strips. Also weigh a piece of copper, about 1·5–2·0 grams.

Put the smaller quantity of copper into a 6 × 1 test-tube and dissolve it in the least possible quantity of concentrated nitric acid Evaporate carefully to dryness in the tube and heat the residue till decomposition of the nitrate is complete.

When the tube is cold, warm the oxide with concentrated hydrochloric acid, add the weighed copper and boil gently till the liquid is clear Pour the contents of the tube into a beaker of water, and note the white solid formed Remove the piece of copper, wash, dry and weigh it.

In this experiment, when the oxide is warmed with hydrochloric acid, a green solution of copper chloride is formed. The added copper reacts with this, forming another chloride of copper containing the same weight of chlorine.

Hence the weights of copper which combine with the same weight of chlorine are known.

300. CHLORIDES OF MERCURY

E. J. Williams

Calomel and mercuric chloride, following the method given in experiment No. 248, afford an experimental illustration of the Law of Multiple Proportions. Since the chlorides of mercury are anhydrous and obtainable in a high degree of purity, they give better results than the hackneyed reduction of the oxides of copper or lead. This is also due to the possibility of using larger weights of the substances than is customary in ordinary equivalent weight determinations. As much as 10 grams of the chloride can be treated if desired.

MOLECULAR WEIGHTS IN SOLUTION

301. MOLECULAR WEIGHT BY DEPRESSION OF THE FREEZING POINT OF CAMPHOR

E. W. Wignall

Ten milligrams of the substance (or more, if this quantity cannot be weighed sufficiently accurately) are mixed with a known weight, about 10–20 times greater, of camphor, of which the melting point has been specially determined, in an ignition tube or small test-tube which has been cleaned with chromic acid and dried. The tube is closed by a cork, through which passes a knitting needle or a glass rod to stir the mixture, and is plunged into an oil bath at a temperature just above the melting point of the camphor. The mixture is well stirred, but

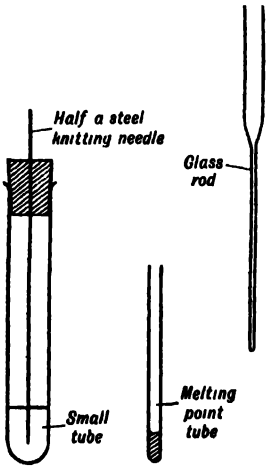


FIG. 209.

cooled again quickly to avoid loss of camphor by sublimation. The solidified mass is scraped out, the tube being broken if necessary, and mixed again in a small glass mortar or on a watch glass. In a melting-point tube with a round, not pointed, end, sufficient of the mixture is then taken to form a pellet about as long as the tube is wide (e.g. 1 mm.), when pressed down with a drawn-out glass rod having a rounded tip.

The melting-point tube is heated quickly to within 40–50° of the melting point of the pure camphor, then slowly until melting begins, after which the heating should be very slow. A skeleton of solid is then seen to be suspended in the liquid; it is observed through a lens and the temperature of its disappearance noted.

A thermometer graduated to fifths or tenths of a degree is desirable but not essential.

Calculation of Molecular Weight.—The temperature observed is the *freezing point* of the camphor containing the dissolved substance: the depression of a freezing point has thus been observed without the use of a Berkmann thermometer. The depression is 40° for 1 gram-molecule dissolved in 1 kilogram of camphor; from this the molecular weight is calculated in the usual way.

Notes.—The method is naturally not applicable to substances insoluble in melted camphor, or to those which decompose at the temperature employed. Picric acid, acetanilide and naphthalene are very suitable, and will give results accurate within 5 per cent.

Errors arise from inaccurate weighing, imperfect mixing, loss of camphor by sublimation, or too rapid heating of melting-point bath. If a round-ended melting-point tube is not used, or the mixture is not pressed down well, air bubbles remain suspended, and may be mistaken for the solid skeleton.

For microchemical molecular weight determination, the *whole* operation is carried out in a melting-point tube.

This method, which is applicable to the majority of

solid organic compounds, is due to Karl Rast (*Berichte*, Vol. 55, 1051 (1922)), and is much employed in research work.

302. MOLECULAR WEIGHT BY LANDSBERGER'S METHOD

Oxford, 1921



FIG. 210.

Fig. 210 shows a modification of apparatus used for molecular weight determination by Landsberger's method, which is compact and easily constructed in any laboratory.

The diagram is almost self-explanatory. The larger limb of the inner U-shaped tube is graduated with an arbitrary scale by means of hydrofluoric acid, and is calibrated by running water in from a burette, with the thermometer in position. This tube contains the solution heated by the vapour of solvent boiling in the outer tube. The upper part of safety tube and thermometer, and the condenser for issuing vapour, are not shown in the diagram.

303. RICHARDS'S METHOD FOR FINDING FREEZING POINTS OF SOLUTIONS

W H Barrett

The method of Richards for the determination of lowering of freezing point is described briefly; its simplicity and advantages are not generally recognised.

The apparatus needed is a ½ litre flask, having a cork with two holes—one for a thermometer divided in $\frac{1}{10}$° C. and reading over a small range near 0° C., and one for the introduction of a pipette. A mixture of water and ice (made from distilled water) is put in the flask, which is

surrounded by ice; the temperature is read when constant, giving the zero point. Enough salt solution is added to give a readable depression on the thermometer, and the temperature is read when steady; some of the solution is at once removed with a pipette from round the thermometer bulb and analysed. By successive additions of salt solution in this way, a straight line is obtained by plotting temperature against concentration; from the slope of this line, the molecular lowering of freezing point is calculated. The salt chosen should be one easily estimated volumetrically, e.g. KCl, using standard solutions of silver nitrate and ammonium thiocyanate.

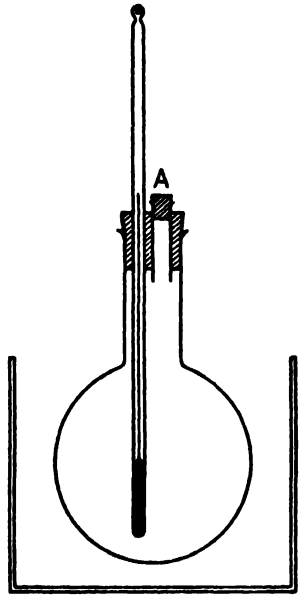


FIG. 211.

ORGANIC CHEMISTRY

304. ABSORPTION IN ORGANIC COMBUSTIONS

E. W. Wignall

The following method may perhaps not be known to all, though in research and general practice it has completely superseded the use of the troublesome potash bulbs.

Between the combustion tube and the sulphuric acid bubbler through which the waste oxygen escapes to the air, there are three U-tubes. These are about 4 in. long × ½ in. diameter, and are provided with side tubes and ground-in stoppers which are also taps, opening or closing the side tubes. In one side tube of the first U-tube there is a bulb and a splash trap.

The tubes are first thoroughly cleaned with chromic acid mixture, washed and perfectly dried. After filling —with materials described below—to within about an inch of the stopper tap, which has also been cleaned from all grease, a small wad of fresh glass wool is inserted at the top of each limb, care being taken that none remains on the ground glass surfaces to spoil the taps. The latter are then greased with the smallest quantity of vaseline necessary to remove all air streaks. The grease which inevitably collects in the hole of the stopper may be conveniently removed by passing a pipe cleaner through the side tube and the tap hole, and pushing the grease on to the opposite side of the stopper.

The absorbents used, which must be introduced before greasing the taps, are :

Tube 1 (which has a bulb on one side tube and is used for absorbing water) ; very fine granular calcium chloride.

Tube 2 (for absorbing carbon dioxide) : in the first limb, and most of the second, very fine granular soda lime, which should not be too dry ; at the top of the second limb some broken solid potash.

Tube 3 (a guard tube for carbon dioxide) : the first limb is filled similarly to the second limb of tube 2 ; the second limb has one-third soda lime, above which is an equal quantity of broken potash ; and lastly, the same quantity of fine calcium chloride, to keep back any water removed from the soda lime by the oxygen stream.

Before being used for the first time, tube 1 is filled with dry carbon dioxide and allowed to stand some time, to remove any alkalinity from the calcium chloride, after which the carbon dioxide is replaced by oxygen.

For the combustion—after the combustion tube has been burnt out for several hours—that side tube of the calcium chloride tube which is provided with a water trap is pushed just through a bored rubber stopper tightly fitting the combustion tube. The other side tube is joined by a small piece of narrow *pressure* tubing to the first limb of the first soda lime tube, and, similarly, the

first limb of the soda lime guard-tube to this, with, lastly, the sulphuric acid bubbler. The latter is preferably of the wash-bottle type, with allowance for suck back.

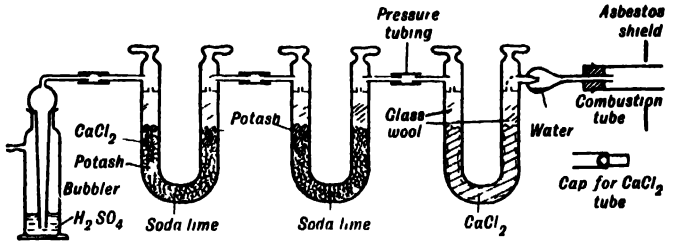


Fig. 212

The combustion tube, without the substance to be analysed, is heated to redness again for an hour, while oxygen[1] is passed slowly through tube and absorption apparatus. The fore end of the combustion tube is then allowed to cool for half an hour while the rear remains red hot; at the same time, all the taps of the U-tubes are closed, and the tubes detached. (This requires care, particularly at the end of the combustion when the pressure tubing has softened slightly and grips strongly; the tubes break easily at the bottom of the U if strained.)[2]

The rubber stopper is removed from the calcium chloride tube and a rubber tube and glass rod cap substituted; to the end of the combustion tube, an ordinary calcium chloride drying tube is attached.

The U-tubes, which may conveniently be made to rest in slots cut in the top of a cardboard box, are placed in the balance room for half an hour. At the end of this time they are weighed, being placed flat on the balance pan. It is best to wipe them gently with a clean dry cloth; but since it is important not to remove any grease from the tops of the stoppers, it may be found that, unless care is taken, wiping decreases the accuracy. It

[1] Oxygen is to be preferred to air for almost all combustions.

[2] It is often convenient to cut away the rubber tubing by slicing with a safety-razor blade.

is to be noted that the tubes are weighed full of oxygen, as they will be at the conclusion of the combustion.

The tubes are now replaced, the substance introduced into the combustion tube, and the combustion carried out in the usual way. Unlike potash bulbs, the absorption system gives little indication of too rapid combustion—but this must always be avoided, as it can be by never heating the substance by the flame until it has for a time been subjected to heat thrown down by the tiles.

At the conclusion of the combustion, allowing sufficient time for sweeping out, and making sure that no water remains at the end of the combustion tube (which may be heated gently by heat thrown down from an asbestos card, or from below by a taper), the tubes are closed, detached, cooled in the balance room, and weighed as before—always with or without the cap on the water tube, according to the method chosen for the first weighing.

In the ordinary way, the weight of the second carbon dioxide absorption tube will not change more than a fraction of a milligram, which may be neglected. Larger changes, increases in weight, will be due to too rapid an oxygen stream being employed, or to exhaustion of the first carbon dioxide tube. The weights of carbon dioxide absorbed in the two tubes should then be added, and the result will still be accurate, unless the combustion was much too fast.

The first carbon dioxide tube will last out a number of combustions, but must be refilled as soon as exhausted; the second tube will last almost indefinitely. The water absorption tube will last the longer if the drops of water in the trap are shaken out after each combustion; after a time the calcium chloride will cake together at the top, and the tube must be filled as soon as this cake can no longer be broken up by *very gentle and careful* prodding with a knitting needle or rod.

The advantages of the modern method of absorption are obvious: there are no liquids to spill, and the tubes can be weighed flat on the balance pan. Moreover, absorption is more efficient, and the same tubes may be used for many combustions.

305. PREPARATION OF ACETAMIDE

W. H. Barrett

Acetamide may be obtained in almost theoretical yield by mixing equal molecular proportions of ammonium acetate and glacial acetic acid, and distilling with a fractionating column at such a rate that the temperature at the top of the column is not above 104° C. The preliminary distillation is continued until nothing more distils over under the conditions stated. A residue of pure acetamide remains in the flask.

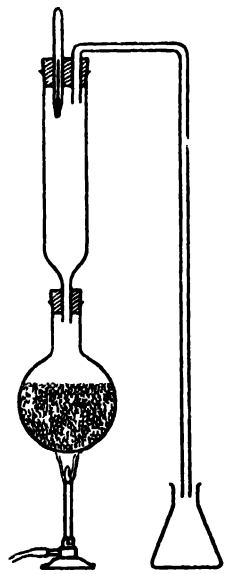


FIG. [illegible].

ANOTHER METHOD

To obtain a good yield of acetamide, use the apparatus shown. The flask is three-quarters filled with ammonium acetate crystals and heated so that the thermometer at the top of the air condenser is kept between 100° and 105°. This temperature is maintained so long as any water drips from the side tube. When no more water is given off, it will be found difficult to keep the temperature steady. Then stop heating, transfer contents of flask to distilling flask with air condenser, and distil in the usual way, collecting that portion which distils above 180°. A redistillation gives a good specimen of acetamide.

306. BORSCHE'S REAGENT FOR ALDEHYDES AND KETONES

Birmingham

This is a modification of the phenyl hydrazone reaction, by the use of 2·4 dinitro-phenyl hydrazine instead of phenyl hydrazine itself. The advantage of using Borsche's reagent is that the precipitation of the hydrazone takes place almost at once, and the precipitate is easily filtered, washed, dried and recognised by its melting point.

Preparation of the Reagent.—A solution of 4·6 grams of sodium in 100 c.c. of methyl alcohol is prepared. This is added slowly to a solution of 40·6 grams of 2·4 dinitrochlorobenzene (obtainable from British Drug Houses) in 100 c.c. of hot methyl alcohol. Eleven grams of hydrazine hydrate (90 per cent.) in 50 c.c. of methyl alcohol are then added, and the whole is warmed in a flask on the water bath under a reflux for fifteen minutes. The reaction product is then cooled, filtered at the pump, washed with methyl alcohol till free from sodium chloride, and dried on a water bath. It is a fine red crystalline powder and the yield is almost quantitative. The reagent is prepared by dissolving 1 gram of the substance in 99 c.c. of methyl alcohol and adding 1 c.c. of concentrated hydrochloric acid. Solution may be aided by warming for some time on a water bath.

When a few c.c. of this reagent are warmed with a few drops of any aldehyde or ketone, a fine crystalline precipitate of the hydrazone appears. The reaction takes place almost instantaneously with aromatic compounds, but a rather longer time (one or two minutes) may be necessary with aliphatic compounds, in which case the precipitation is aided by warming and adding one or two drops of water. The colours of the precipitates vary from light yellow to deep red.

OSMOTIC PRESSURE

307. THISTLE-FUNNEL—PARCHMENT PAPER EXPERIMENT

A. Haywood

To prevent leakage, which is the usual cause of failure, proceed as follows: Select a piece of parchment paper free from pin-holes, soak well, fold without straining over the mouth of the thistle-funnel and bind tightly with thread or string. Tear away the loose paper to within about ½ in. of the binding and turn back, away from the funnel, to form a cup. After drying, run hot paraffin wax into the cup and folds and also coat the string and paper outside, as far as the rim, with the wax.

Filling.—Any difficulty caused by the narrow stem of the thistle-funnel may be overcome by drawing out a broken test-tube for use as a filling funnel and passing the capillary right down into the bulb.

308. A GLYCERINE-GELATIN MEMBRANE

Hugh Richardson

Instead of using a porous battery cell impregnated with copper ferrocyanide, a cell coated internally with glycerine-gelatin (e.g. the familiar jellygraph compound of the masters' common room would do) may be substituted. A large rubber cork and several metre lengths of glass tubing are required. The cell is filled with treacle (treacle is a handy sugar solution), fitted with cork and tube and then immersed in an outer vessel of water. In a few days the internal and diluted sugar solution will have risen several feet, and further lengths of glass tube can be added with rubber junctions. The experiment may end when organic fermentations set it; possibly these could be postponed by carbolic acid.

309. OSMOSIS EXPERIMENTS

Birmingham,

The following is a neat modification of the usual osmotic pressure demonstration in which a copper ferrocyanide membrane is employed to illustrate semi-permeability.

Small pills are prepared by mixing 2 parts of copper sulphate with 1 part of cane sugar, grinding the mixture together and rolling into small pills, after the addition of a little water.

A solution is next required consisting of a warm mixture of :

500 c.c. of water.

100 c.c. of 10-per-cent. gelatine solution (a convenient stock solution).

50 c.c. of saturated potassium ferrocyanide solution.

50 c.c. of saturated salt solution.

The warm mixture is put in a gas jar and allowed to cool. Just before it sets, one or two of the prepared pills are dropped in.

Very pretty growths result after a time as the pill material dissolves, and the copper sulphate reacts with potassium ferrocyanide in the solution to produce a semi-permeable membrane of copper ferrocyanide, through which water molecules pass freely to the inside and produce the observed effects.

(There seems to be some doubt as to the function of the sodium chloride employed in the solution, but better results are obtained if it is present.)

POLYMORPHISM

310. MERCURIC IODIDE

Oxford, 1921

Sublime pure mercuric iodide from a dish on to a filter paper ; the yellow colour persists for a long time. Write

firmly on the paper with a clean glass rod : transformation to the red form takes place instantaneously under pressure.

311. SILVER AND CUPROUS MERCURIC IODIDES

R. G. Durrant

Silver-mercuric iodide assumes a yellow form at ordinary temperatures, and has a sharp transition point at 40° C. ; so if filter paper, impregnated with this double salt, be waved over a Bunsen, it becomes suddenly suffused with a deep flush, which rapidly reverts to pale yellow on waving the paper.

Deep red cuprous-mercuric iodide turns black when heated to about 70·5° C. The writer finds the following method an impressive way of showing the sudden reverse change : Confront the audience with the warm, black surface facing them ; touch the back of the paper with the finger-tips. The audience then perceives what might be described as drops of blood on a black background.

Preparation of Cuprous-mercuric Iodide.—A solution containing 6 8 grams mercuric chloride is mixed with another containing 8·3 grams potassium iodide. The precipitated mercuric iodide is washed several times with water by decantation and dissolved by a mixture of 8·3 grams potassium iodide in 50 c.c. of water. The solution is filtered, if necessary, to get a perfectly clear solution of potassium mercuric iodide, $K_2[HgI_4]$. To this is added 12 grams of $CuSO_4.5H_2O$, dissolved in water, to give a concentrated solution. A dark red crystalline precipitate is formed. Pass sulphur dioxide through the mixture to complete precipitation. Wash and dry in a steam oven Yield about 20 grams.

Preparation of Silver Mercuric Iodide.—Prepare the potassium mercuric iodide solution as above and precipitate the silver salt by the addition of silver nitrate.

Either of the iodides can be rubbed on a cut filter paper

to produce a lemon-coloured (Ag), or red (Cu) disc. The transition is not so sharp with the silver compound as it is with the copper.

312. RHOMBIC AND MONOCLINIC SULPHUR

G. F. Hood

Crystallise sulphur from solution in ethane tetrachloride, (i) below the temperature of transition from rhombic to monoclinic sulphur; (ii) above this temperature. Ethane tetrachloride is most suitable on account of its high boiling point.

A small flask, fitted with a grooved cork carrying a thermometer, is employed to contain the solutions. Sulphur is dissolved in the solvent, until, by trial, it crystallises out (i) at about 80° C., (ii) at 100° C., the heating being done by immersing the flask in a water bath. The student should be required to state beforehand what results might be expected, and he should then examine the crystals he obtains under a low-power microscope.

Since the transition point is about 96° C., we might expect to obtain (i) rhombic sulphur, as usual; (ii) monoclinic sulphur. This will be found to be the case. The crop of crystals obtained in (ii) will, while it is still undisturbed in the flask, closely resemble an ordinary lecture preparation of prismatic sulphur.

PREPARATIONS

313. RECOVERY OF SILVER FROM SILVER RESIDUES

P. W. Oscroft

Add strong hydrochloric acid to residues, shake well and allow to settle. Decant liquid and treat residues by method (1) or (2).

(1) Rinse wet precipitate into porcelain dish, acidify with sulphuric acid and lay strips of zinc (free from lead)

on the silver precipitate; let stand for 24 hours. The spongy mass of silver is freed from zinc, washed and dissolved in nitric acid.

(2) Dry the residue and mix with twice its weight of sodium and potassium carbonates in equal proportions. Transfer to a crucible and heat in a furnace.

N.B.—The crucible must be tapped to cause the melted silver globules to unite. When cool, the crucible, if broken, should yield a button of silver.

314. RECOVERY OF SILVER FROM SILVER RESIDUES (ALTERNATIVE METHOD)

W. H. Barrett

The silver salt must be in the form of the chloride, bromide or iodide. It is *fused* in a porcelain crucible, which is then placed in a shallow beaker or crystallising dish. Alongside it is placed a second crucible, E, containing mercury. A small piece of platinum foil is attached to a platinum wire, B, the other end of which is wrapped round a zinc stick, C, dipping in the mercury. The whole is covered with dilute sulphuric acid (1·20) and allowed to stand 24 hours. A glass rod, A, resting on the platinum foil, keeps it in contact with the surface of the solid silver chloride in D. At the end of 24 hours, the silver chloride will be all reduced to silver, which needs only washing, drying and heating.

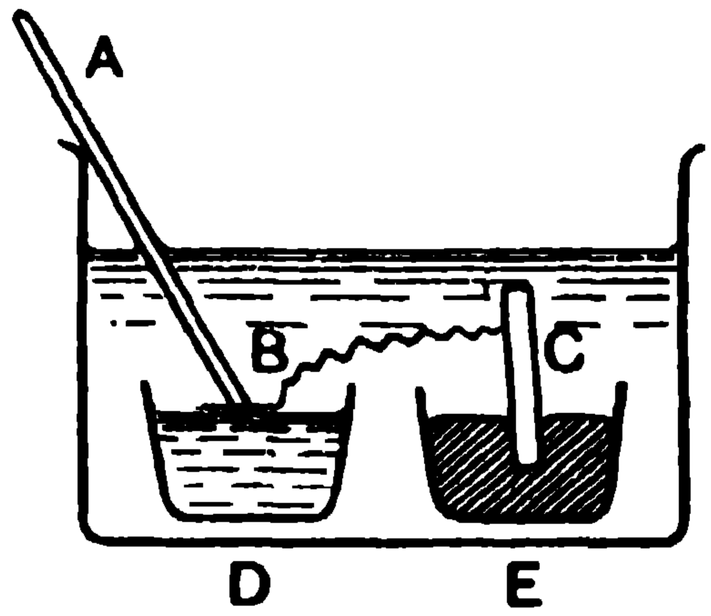


FIG. 214.

315. GREEN MANGANOUS SULPHIDE

Birmingham

One volume of ·880 ammonia is added to 5 volumes of 5N ammonium chloride. To this mixture a saturated solution of manganous sulphate is then added until a

faint permanent precipitate just *fails* to appear, after which the resulting mixture is warmed almost to the boiling point. On addition of yellow ammonium sulphide, buff-coloured manganous sulphide precipitates, but on continued warming, this soon passes over into the green variety which is stable.

316. ELECTROLYTIC PREPARATION OF INORGANIC PIGMENTS, LEAD CHROMATE, ETC.

Birmingham

When an aqueous solution of a chromate is electrolysed with a lead anode, an adherent crust of lead chromate forms and the action ceases. But in the presence of excess of a salt having an anion that forms a soluble lead salt, precipitation appears to take place a short distance from the anode surface, and lead chromate streams away from it.

Apparatus.—A gas jar serves to contain the electrolyte. Small lead sheet electrodes, about 10 × 5 cm., are used, and a diaphragm of parchment paper with a few small holes in it serves to retard mixing when hung between the electrodes. The electrolyte contains 1·8 gram/litre of potassium chromate and 15·5 gram/litre of potassium chlorate. The current density is about 0·4 amp. per sq. dm. of electrode surface. A voltage of about 8 will be right for the apparatus described. The method may easily be modified to prepare white lead, lead arsenate, lead dioxide, etc. For white lead, the electrolyte consists of 12 grams of potassium chlorate and 3 grams of sodium carbonate in a litre of water. C.D. 0·4–0·6 amp. E.M.F. as above. A slow stream of carbon dioxide is passed in behind the cathode in such a manner as to disturb the liquid as little as possible.

LITERATURE.—Luckow, *D.R.P.*, 91707. *Practical Methods of Electro Chemistry*, F. M. Perkin (Longmans).

317. EXPERIMENTS WITH SILICA

G. H. Benham

(1) Heat in a small tube a mixture of sand and magnesium powder. Note the glow. (2) Put product into test-tube and add concentrated hydrochloric acid. Spontaneously inflammable gas is given off. Heat with the acid until there is no further action. (3) Wash the residue by decantation in test-tube and add caustic soda solution. Hydrogen is given off. Filter. (4) Add concentrated hydrochloric acid. There is no apparent result. (5) To the solution add ammonium hydroxide. A dense white precipitate is formed.

PROBLEMS

318. COPPER SULPHATE AND FERROUS SULPHATE

G. F. Hood

When hot concentrated solutions of copper and ferrous sulphates are mixed and allowed to crystallise, fine blue-green monoclinic crystals are deposited. Examine these with the object of finding whether a true double salt or a mixed crystal has been formed, and attempt to express the composition by a formula.

If a double salt has been formed, we might expect the atomic ratio of iron : copper to be a simple one and to be unaltered when the substance is recrystallised (though this last is not always the case). If a mixed crystal has been formed, then the above ratio will not necessarily be simple.

The crystals appear to be isomorphous with ferrous sulphate, not with copper sulphate, and hence we might expect to find seven molecules of water of crystallisation. The iron may be determined by permanganate and the copper by the cyanide method, or otherwise.

An actual experiment gave the following results:

7·335 grams of the crystals contained 1·145 gram of iron and ·3675 gram of copper. The ratio copper : iron = ·32, which is not in any simple atomic ratio. Hence we conclude that the substance is a mixed crystal.

Further, the above weights of iron and copper correspond to 5·685 grams of $FeSO_4$, $7H_2O$, and 1·663 grams of $CuSO_4$, $7H_2O$—total 7·348 grams, which is practically the weight taken. Hence the formula of the crystals is $(Fe,Cu)SO_4$, $7H_2O$.

The qualitative reactions of this salt are of interest. If we apply the common tests for copper and iron, we find that :

Ammonium hydroxide gives practically no blue colour, but a brown precipitate of ferric hydroxide.

Sodium hydroxide gives an orange-red precipitate of cuprous and ferric hydroxides.

Ammonium thiocyanate gives red ferric thiocyanate and an immediate white precipitate of cuprous thiocyanate.

Hence the salt behaves as though it was a mixture of cuprous and ferric sulphates.

The student should be required to give some explanation of this.

319. THE ACTION OF OXIDISING AGENTS UPON SODIUM THIOSULPHATE

G. F. Hood

Compare the action of strong oxidising agents on sodium thiosulphate with that of weak oxidising agents.

As weak oxidising agents, we may take iodine (in potassium iodide solution), the action of which is well known, copper sulphate and a ferric salt ; as strong oxidising agents, bromine water and chlorine water, both saturated.

A rough quantitative estimation of the reacting quantities is made by running a solution of thiosulphate into a solution of the reagent (*not vice versa*) and noting the colour change for the end point, or, in the case of chlorine water, using an outside indicator.

We find that the weak oxidising agents produce no sulphate, but tetrathionate, the copper and ferric salts being reduced to the cuprous and ferrous states. The strong oxidisers, on the other hand, turn the thiosulphate completely to sulphate.

QUALITATIVE ANALYSIS

320. SPOT TESTS

D. B. Briggs

Special Reagents Required

Benzidine dissolved in acetic acid.
Alcoholic diphenyl carbazide.
Cinchonine.
Alcoholic dimethyl glyoxime.
Alcoholic alizarin.

General Plan of the Tests

A drop of the solution under test is allowed to react with a suitable reagent on filter paper, when characteristic colours and stains are observed.

To indicate the Presence of Lead in Solution

(1) One drop of an ammoniacal solution of hydrogen peroxide is placed in the middle of a piece of filter paper, and one drop of the lead solution under test is dropped on to it.

After standing for a short time, a deep blue coloration appears when the spot is treated with a drop of benzidine dissolved in acetic acid. This test will recognise the presence of lead to the extent of one part in 33,000. Bismuth interferes with its action.

(2) Potassium iodide is added to a strong solution of stannous chloride so that the mixture, when shaken, is semi-solid. A strong solution of cadmium nitrate is then added, drop by drop, until a clear solution results. (Hydro-

chloric acid or potassium thiocyanate can be used instead of cadmium nitrate, but this diminishes the sensitiveness.) This reagent does not keep well and must be made as required.

A drop of the solution to be tested for lead is placed on a filter paper, followed by a drop of dilute sulphuric acid. The spot is then washed with dilute sulphuric acid. (If other metals are present, they are washed beyond the lead sulphate spot.) On the addition of one drop of the reagent prepared as above, an orange colour is seen.

If bismuth is present as well as lead, the stain is brown.

To test for the Presence of Mercurous and Mercuric Ions

(1) A filter paper is spotted with alcoholic diphenyl carbazide. A drop of the test solution added will give a blue colour, if mercury is present to the extent of as little as 0·2 gram per litre.

Both copper and cadmium interfere with the test, but since the sulphides of these metals are soluble in nitric acid, they can be previously removed.

In this test, if mercury is present both in the mercurous and in the mercuric states, then the solution to be tested, when shaken with a benzene solution of diphenyl carbazide, gives a blue coloration (*ic*), and at the junction of the benzene-water layer a flocculent precipitate is seen, due to the mercurous ions.

(2) Mercuric ions, in the absence of mercurous and silver ions, give a black spot with manganese nitrate and caustic soda.

(3) Detection of Silver in Presence of Mercury(ous)

The mixed chlorides of the two metals are first obtained. On the addition of a spot of ammonia, a black stain results. This is then removed with a spot of bromine water. On subsequent treatment with man-

ganous nitrate and ammonia, the appearance of a black spot indicates the presence of silver.

To test for the Presence of Bismuth

The spot reagent required is made by mixing 1 gram of cinchonine in very dilute nitric acid and 2 grams of potassium iodide per 100 c.c. If bismuth is present in the drop of solution added to a drop of the reagent on filter paper, an orange colour results.

To detect Mercury, Copper, Lead and Bismuth together

The same test as for bismuth alone is carried out, when colours are obtained from the middle of the spot outwards in the order: white (mercury), orange (bismuth), yellow (lead), brown (copper); the last on the extreme edge.

To detect Cadmium

Filter paper is moistened with a saturated solution of diphenyl carbazide in 90 per cent. alcohol previously saturated with potassium thiocyanate, and containing a little potassium iodide. A drop of a cadmium-containing solution added to this gives a red-violet colour.

Copper does not interfere.

To detect Cadmium and Lead when present together

The same test as for cadmium alone is performed, when the lead gives a yellow colour inside the cadmium violet.

To detect the Presence of Tin

(*a*) *In the Stannous State.*—A mercuric chloride test paper is treated with a drop of the solution to be tested, and then a drop of aniline is superimposed on it. A black stain results. Other metals do not invalidate the test.

(*b*) *In the Stannic State.*—Before performing the above

test, the tin must be reduced to the stannous state by means of magnesium and hydrochloric acid.

(By using a stannous chloride test paper, mercury can be detected.)

Another Test for Tin (Stannous)

If a drop of a solution containing stannous chloride is added to a spot of ammonium molybdate reagent on filter paper, an intense blue coloration is obtained. On warming the filter paper carefully over a flame, the blue colour disappears. If arsenic is present, the blue colour cannot be removed by this treatment. Very small traces of arsenic suffice to do this.

To detect Aluminium

A filter paper is saturated with ferricyanide solution. The drop of solution to be tested is treated with ammonia and alcoholic alizarin, and dropped on to the treated filter paper. If aluminium is present, a pink ring on a violet background is obtained.

To detect Nickel

Paper saturated with sodium phosphate solution, and the test spot treated with alcoholic dimethyl glyoxime, gives a pink ring if nickel is present.

To detect Chromium (in the Chromic State)

The solution to be tested is oxidised by warming with silver nitrate and caustic soda, followed by the addition of ammonium nitrate solution to convert the caustic soda to sodium nitrate, and to dissolve silver oxide. During the operation, the chromic salt is oxidised to chromate, which can be recognised by the addition of a drop of silver nitrate with the production of red silver chromate; or by the addition of a solution of benzidine in acetic acid, which gives a blue colour.

Note.—In the case of nickel, cobalt and lead, oxidation can be brought about by the use of silver nitrate and

caustic soda, but the black stain produced cannot be removed by ammonium nitrate.

If ammoniacal silver nitrate is employed, a deep black stain can be obtained with manganese salts, but not with salts of copper, nickel, lead or chromium.

321. SUPPLY OF HYDROGEN SULPHIDE

J. Kewley

The diagram is self-explanatory.

The obvious advantages are the following:

A large charge of iron sulphide can be used, so that the apparatus need seldom be disturbed. The acid in the

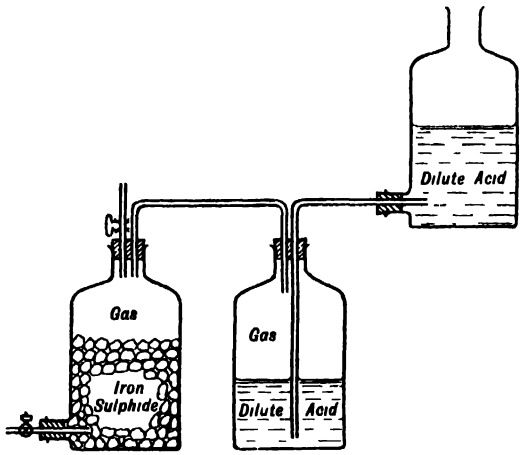


FIG. 215.

reservoir remains of constant strength. The acid which comes into contact with the sulphide is completely exhausted and can be drawn off from time to time. The apparatus is cheap and easily made.

322. SUPPLY OF HYDROGEN SULPHIDE

F. R. L. Wilson

Fully slaked lime is powdered, screened through a very fine sieve, and mixed with about three times its bulk of

sawdust, previously damped. The two substances are thoroughly incorporated with each other, the degree of dampness being such that the mixture does not stick to the hands when kneaded. If too damp, dry sawdust can be added. Thorough mixing is necessary, and also the right degree of moisture, since if too much is present, the water generated by the action of carbon dioxide on the sulphydrate will make it too wet, and not sufficiently porous ; if too dry, the hydrogen sulphide is not absorbed. This mixture is filled into soda-lime towers, the space at the bottom being first filled in with dry sawdust. A small portion of the mixture is tested first. A stream of hydrogen sulphide is passed in at the bottom, several towers being arranged in series. All the gases generated from the ferrous sulphide, except hydrogen sulphide, will escape.

In order to generate hydrogen sulphide, carbon dioxide from a Kipp's apparatus is passed in at the bottom of the tower, and two volumes of gas will be set free for every volume of carbon dioxide which acts.

Incomplete saturation of the calcium hydroxide with hydrogen sulphide in the first instance is to be avoided, since, although hydrogen sulphide will be set free, a part of this will combine with the free calcium hydroxide, and a partial vacuum will result when the taps are closed. Always pass in carbon dioxide before opening the hydrogen sulphide exit, otherwise there is a danger of liquid, through which it is desired to pass the gas, being drawn back and of the tower being spoiled.

The course of exhaustion of the mixture is seen by noting to what level a change in colour from yellow to dirty white has taken place.

The presence of carbon dioxide in the gas may cause trouble if hydrogen sulphide is used in the third group in qualitative analysis. This can be easily detected by passing the gas through barium hydroxide solution, when a precipitate of $BaCO_3$ will be thrown down if carbon dioxide is present.

Advantages: (1) A very large supply of gas can be got from a single tower, and reserve towers can be kept in readiness; (2) purity of the gas; (3) absence of smell when the tower is not in use, and also when a spent tower is emptied.

323. SENSITIVE TEST FOR HYDROGEN PEROXIDE

F. B. Finter

Titanic sulphate is the most easily applied and sensitive test which will distinguish hydrogen peroxide from other oxidising agents. The limit of hydrogen peroxide concentration which is detected by the chromic acid and ether test is given as 1 in 80,000; but titanic sulphate is sensitive to concentrations of about 1 in 1,000,000 and is said to give a distinct light yellow colour when the concentration is only 1 in 180,000.

RATE OF REACTION

324. ZINC AND SULPHURIC ACID

H. G. F. Micklewright

Measurement of the rate of evolution of hydrogen when zinc dissolves in dilute acids can be made with the apparatus frequently used in determining the equivalent of a metal by displacement of hydrogen, the volume of gas being measured by driving water out of a Winchester quart through a syphon. The flask containing the metal and acid should be immersed in water and gently shaken.

A large excess of commercial granulated zinc, say 50 grams, should be used; it should first be treated with the acid until the reaction is brisk, and then washed with water and allowed to drain. If the activities of different acids are to be compared, it is important that the zinc should have been similarly treated in each case. N/1 and

N/2 H_2SO_4 and HCl are convenient acids to use; 50 c.c. is a suitable volume. The acid must be added as quickly as possible; the stopper is then inserted, and the clip on the syphon released. Readings are taken at ¼- or ½-minute intervals.

For lower forms, it is sufficient to plot "volume" against "time." If this curve only is required, the previous treatment of the zinc may well be omitted, in which case the "induction" period will be shown on the graph. More advanced forms, by plotting "time" against $\log \frac{a}{a-x}$, can show that the rate of change is proportional to the amount of acid remaining at any instant. In this case a is calculated from the total volume of acid used.

By plotting the graphs for N/2 HCl and H_2SO_4, it can be shown that the former is the "stronger" acid.

The rate of evolution of carbon dioxide when marble dissolves in hydrochloric or nitric acid can also be measured.

325. THE LIBERATION OF SULPHUR FROM SODIUM THIOSULPHATE

Birmingham, 1931

Three solutions are needed:

(*a*) 20 grams of sodium thiosulphate crystals per litre (·08N).

(*b*) 10 grams of sodium thiosulphate crystals per litre (·04N).

(*c*) 5 grams of sodium thiosulphate crystals per litre (·02N).

Four parts of each solution are placed in each of three test-tubes, together with one part of bench hydrochloric acid or sulphuric acid, the acid being added quickly to the thiosulphate and the mixture shaken. If time observations are made, it will be found that solution (*a*) forms a cloud, due to the formation of sulphur, in about 30 secs.,

whilst the times for (*b*) and (*c*) are respectively about 1 and 2 mins.

It helps considerably to view the test-tubes against a background of black paper.

326. IODIC ACID AND SODIUM SULPHITE

Birmingham, 1931

For this experiment, in which an induction period is illustrated, two solutions are required:

A. 1·8 gram of iodic acid per litre.

B. { 1 gram of starch in 100 c.c. of water.
{ 1 gram of $Na_2SO_3.7H_2O$ in 900 c.c. of water.

These two are made up separately and then mixed to give the solution B. Equal volumes of A and B are mixed, and the time is noted with the aid of a stop watch. After a period of induction, the blue colour which indicates the presence of free iodine suddenly appears, when the time is again noted.

The experiment is then repeated after diluting A and B to the same extent before mixing, and time observations are made.

It is found that the concentration of the reactants is approximately inversely proportional to the square root of the period of induction.

327. THE FOREGOING EXPERIMENT WORKED CO-OPERATIVELY

W. Cammack

Prepare the solutions (experiment 326) beforehand and divide the class into convenient groups. Give each group 50 c.c. of each solution in two small beakers. Let each group measure 0 c.c., 5 c.c., 10 c.c., etc., of water respectively from a burette into a larger beaker. At a given signal, all the groups pour their two solutions simultaneously into the water and a seconds clock is started. At the moment that the blue colour appears, the particular set

calls its number and the time is called back. The following shows the results obtained with a second-year form :

No. of Set.	C.c of water added.	Concentration (c).	Time in minutes (t).	$c\sqrt{t}$
1	0	1	5·4	2·33
2	5	0·95	7·20	2·55
3	10	0·91	8·45	2·64
4	15	0·87	9·17	2·63
5	20	0·83	9·35	2·54
6	25	0·80	10·88	2·64
7	30	0·77	11·70	2·63
8	35	0·74	12·65	2·63
9	40	0·71	13·27	2·59

328. AN EASY ILLUSTRATION OF THE EXPONENTIAL OR LOGARITHMIC LAW

G. N. Pingriff

The following experiment may be of interest to chemists and physicists who wish to obtain figures to illustrate this ubiquitous law when first introducing it to their pupils. Results from the rate of cooling do not usually approximate sufficiently closely to the law, while experiments involving the law of mass action are generally more troublesome than the present experiment, which can be carried through in a single lesson with apparatus which is always to hand in a chemical or physical laboratory.

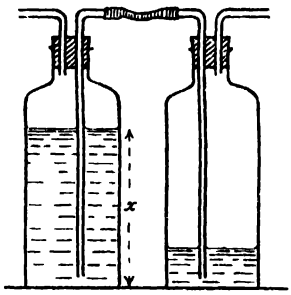


FIG. 216.

Two Winchester quarts are arranged as shown, the connecting tube being full of water and the flow prevented by a clip on the rubber tube. Immediately communication is established, the flow commences, and the rate of flow or rate of change of level is proportional to

the difference of level at that moment. The theory is simplest if we employ two equal-sized bottles, the left-hand one being filled at the beginning to, say, height $2h$, and the right-hand bottle being empty.

Further, let the height of water in the left-hand bottle after t seconds be x cm. The difference of levels will then be $2(x - h)$.

Hence we have $\frac{dx}{dt} = -k(x - h)$

or $\frac{dx}{h} = -kdt$, which, on integration, gives

$$\log \frac{x - h}{h} = -kt,$$

or $$\frac{1}{t} \log \frac{x - h}{h} = \text{constant}.$$

The experiment simply consists of standing a ½-metre rule vertically by the left-hand bottle and taking measurements of x after convenient time intervals. The results may be plotted on ordinary or on logarithmic paper, or the numerical constant may be evaluated from each observation. Close agreement with theory is obtainable: the influence of a disturbing effect during the initial period is noticeable, but this lasts for only ten seconds or so. The only apparent imperfection in the theory is due to varying resistance to motion imposed by the walls of the connecting tubes, but the effect of this is scarcely noticeable. It would be interesting to determine the "time constant" in a few experiments and with connecting tubes of different bores. The time constant is, of course, the T of the expression

$$x - h = h \cdot e^{-\frac{t}{T}}$$

It is clea 'y eq .al to the reciprocal of k as used above.

329. A REACTION ILLUSTRATING SOME OF THE PRINCIPLES OF CHEMICAL CHANGE

H. G. F. Micklewright

It is well known that the estimation of iron in the ferric state by means of its reaction with potassium iodide is successful only in the presence of acid and of excess of the iodide. The investigation of the necessary conditions forms a useful problem for a science set. Solutions of suitable strength are N/10 ferric alum, N/10 sodium thiosulphate, N/1 potassium iodide, and dilute sulphuric acid (1 : 6).

(1) A quantity of the iron solution is mixed with about half its volume of acid, and one or two equivalents of the iodide. Twenty c.c. are withdrawn from time to time and rapidly titrated with thiosulphate. The volume of the latter required will show how the velocity falls as the reaction proceeds.

(2) The influence of concentration on rate of change may also be shown by using definite quantities of the three substances diluted with varying amounts of water, and titrating after, say, three minutes.

(3) Another useful exercise is to investigate the way in which the rate of change and the end-point are affected by the relative proportions of iron salt, iodide, and acid.

(4) Lastly, one can test the influence of temperature. It is obvious that in the early stages of the reaction the results are vitiated by the removal of the iodide during titration ; it is necessary to add the thiosulphate rapidly and to take the reading when the first disappearance of the blue colour occurs.

330. CONDITIONS AFFECTING THE RATE OF CHEMICAL CHANGE

E. R. Thomas

Very few satisfactory experiments exist for this purpose. During an interesting phase of military experience,

the writer discovered a peculiar reaction between dimethylaniline and dilute nitric acid. This was investigated, and it was found possible later, at a meeting of the Chemical Society, to show the influence of temperature, of concentration, of concentration of catalyst and of constitution on the rate of chemical change—the total time occupied being about 10 minutes. The reaction, which involves the gradual formation of 2 : 4 dinitrodimethylaniline, is of interest for its own sake, and a number of experiments other than those here described have been carried out on it.

Experimental

1. Mix 50 c.c. of concentrated nitric acid with 50 c.c. of distilled water.

2. Take 5 c.c. of this mixture in a test-tube and add 7 drops of a 1 per cent potassium nitrite solution (providing the catalyst).

3. Warm gently if a rapid reaction is desired (say to about 30° C.).

4. Add 9 or 10 drops of dimethylaniline and shake. (If too much dimethylaniline is added, violent decomposition occurs.)

A gradual deepening of the yellow solution will be observed. When the colour becomes orange-red, a sudden precipitation of dinitrodimethylaniline occurs. The time taken from the moment of mixing to the instant of the precipitation provides a convenient comparison of the different rates under different conditions.

Keeping constant the quantity of nitric acid solution and its strength (30 per cent. HNO_3 does very well), the temperature (up to 40° C. or so), and the number of drops of dimethylaniline, the number of drops of potassium nitrite solution (presence of HNO_2 from other sources will serve and urea will inhibit the catalysis) may be varied and the different rates compared. Interesting results were also obtained by comparison of dimethylaniline with

diethylaniline and of methyl-propyl-aniline with methyl-isopropyl aniline.

To obtain consistent results, the substances used must be pure. Dimethylaniline may be purified by recrystallisation of its hydrogen-oxalate from water, recovery of the base and redistillation. This is rather a troublesome process, and since the quantity required is not large, it might

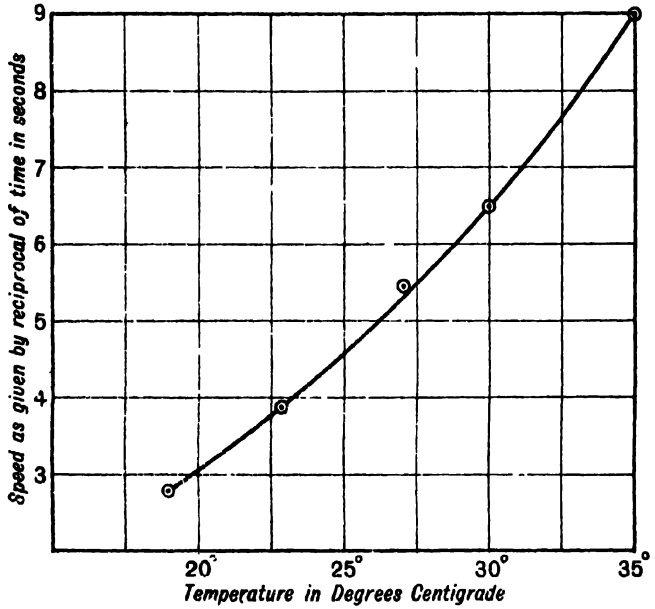


FIG. 217.

be simpler to purchase the pure product. The nitric acid may be freed from nitrous acid by distillation over sodium peroxide. It should then be kept in the dark.[1]

If a slide-holder is made, capable of supporting two test-tubes, the experiments may be shown very well in the lantern. The purchase of expensive glass troughs whose cement is capable of resisting the action of nitric

[1] When showing the effect of temperature or of concentration, the necessary amount of catalyst required to give the desired rate of reaction will, of course, be added in bulk to the diluted pure nitric acid.

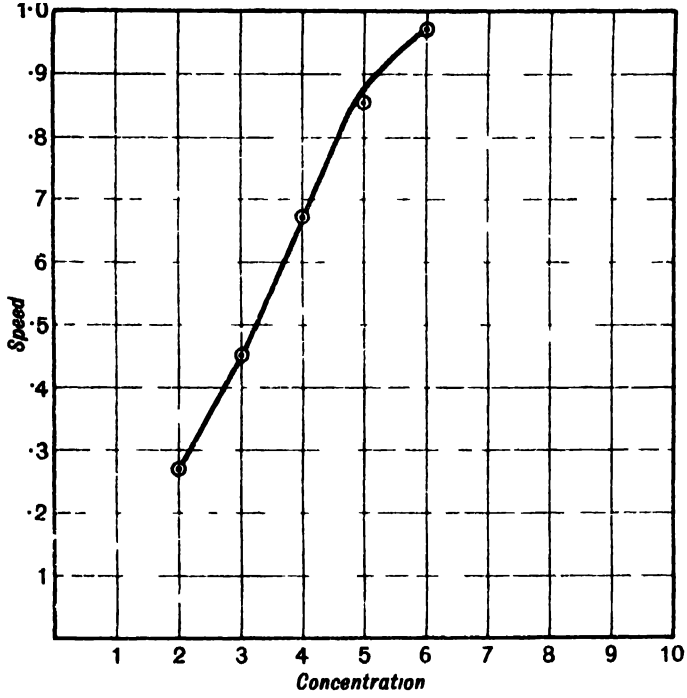


FIG 218.

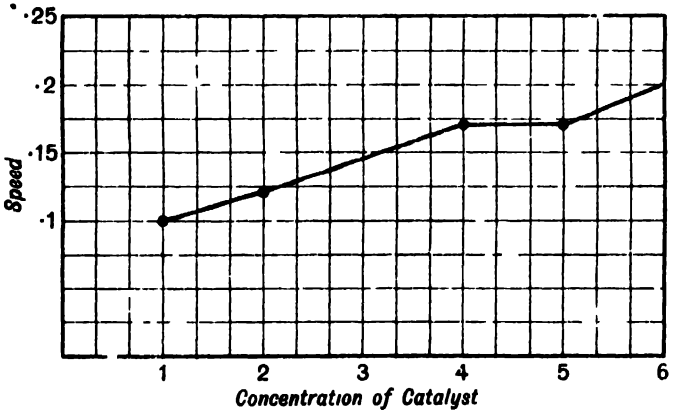


FIG. 219.

acid is not really necessary, because the effects are so marked that the light which comes through the test-tubes is quite sufficient to show them quite clearly.

Three curves are added to show the kind of result which can be obtained after some practice in the observation of this reaction. Fig. 217 (Temperature) is taken from class averages; Fig. 218 (Concentration) and Fig. 219 (Concentration of Catalyst) are results of individual experiments. I am indebted to Mr. G. S. Dean for assistance in the experiments connected with Fig. 219 and to Mr. John White for drawing the curves.

331. OXALIC AND SULPHURIC ACIDS

D. Ll. Hammick and C. R. Prichard

The rate of reaction of oxalic acid with sulphuric acid varies within wide limits, depending on the amount of water present in the reaction mixture. By choosing a suitable concentration in large excess of sulphuric acid, a rate of change can be obtained that is suitable for measurement under school conditions. The reaction has the further advantage that the rate of destruction of oxalic acid can readily be followed by titration with standard permanganate, it proceeds, moreover, smoothly at 100° C., so that thermostat difficulties do not arise.

To about 11 grams of crystallised oxalic acid in a Kjeldahl flask add 200 c c. of 75 per cent. sulphuric acid. Immerse the flask in a rapidly boiling water bath, and shake occasionally until all crystals have dissolved. When the temperature of the reaction mixture reaches 100° C., withdraw 10 c.c. in a pipette[1] and dilute rapidly to 100 c.c. in a standard flask. Titrate this solution with N/10 permanganate to obtain the initial concentration of oxalic acid.

Allow the reaction mixture to remain overnight in the

[1] This must not be done in the ordinary way with the mouth, but by means of an exhausted bottle, fitted with a glass tap and a length of rubber tubing.

water bath at 100° C., and remove successive 10 c.c.s at about two-hour intervals during the next day. Estimate the mass of oxalic acid present in each as before. Data are thus obtained for substitution in the monomolecular equation :

$$2{\cdot}3 \log \frac{a}{a-x} \cdot \frac{1}{t} = k,$$

where a is the initial concentration of oxalic acid and $a - x$ its concentration at time t.

In the following table, a and $a - x$ are expressed as permanganate titres of 20 c.c. of the diluted reaction mixture ; such titres are obviously proportional to concentrations of oxalic acid in the mixture.

$a = 21{\cdot}0$ c.c.

Time (hours)	$a - x$	$2{\cdot}3 \log \frac{a}{a-x} \cdot \frac{1}{t} = k.$
13 08	10 5 c.c.	0 0529
15 33	9 4 ,,	0 0524
17 08	8 6 ,,	0 0524
19 08	7 7 ,,	0 0525
21 00	7 0 ,,	0 0524
22 17	6 5 ,,	0 0520
		Mean 0 0525

Half life period = 13 2 hours

By allowing the reaction to proceed for thirteen hours before the first determination of the velocity constant is made, the perturbations that often affect early values are avoided.

332. BROMINE AND SODIUM FORMATE

H. O. Lipscombe and J. Hunter

Bromine and sodium formate react instantaneously in aqueous solution when no other substance is present, but hydrogen ions retard the reaction in proportion to the amount present in the solution. In order to secure a

sufficient retardation, it is necessary to add considerable amounts of hydrogen ion in the form of hydrochloric acid.

The following solutions are required :

(1) An approximately N/20 solution of bromine, made by running the required volume of bromine from a burette into distilled water.

(2) An approximately N/100 solution of sodium thiosulphate.

It is not necessary to know the exact strength of either of these two solutions, but only their strength in terms of each other.

(3) N/5 or N/10 solution of sodium formate.

(4) Solutions of HCl of known normality, made from pure concentrated acid of known density, using the tables in F. M. Perkin's *Handbook of Chemical Analysis*.

In all experiments, the volume of the reacting mixture is 400 c.c., made up of 200 c.c. of sodium formate solution and 100 c.c. of HCl of known strength, to which are added 100 c c. of bromine water ; the whole is contained in a large flask. A stop-watch, recording to $\frac{1}{5}$ sec., is used to time the reaction, and is set going immediately the bromine has been added to the solution. At noted times, 50 c.c. of the reaction mixture are withdrawn from the vessel and run into excess of KI solution, using a pipette connected with a partially exhausted Winchester quart bottle. The liberated iodine is titrated with the N/100 thiosulphate solution. An allowance is made for the time taken for the pipette to discharge 50 c.c. of liquid into the potassium iodide solution, so the time at which the reaction between the bromine and sodium formate has ceased is taken as the mean time between the commencement and the conclusion of the process.

These readings give the titre of the bromine remaining in 50 c.c. of the reaction mixture, at various times, in terms of the sodium thiosulphate solution, and the equivalent of bromine present in the whole reaction mixture is eight times this volume. The initial titre of the 100 c.c. bromine present in the reaction mixture, in terms

of sodium thiosulphate, is found by measuring 5 c.c. of the bromine water into potassium iodide and titrating as usual.

The reaction vessel may be kept in a thermostat, but this is not absolutely essential.

333. HYDRIODIC AND CHLORIC ACIDS

W. H. Barrett

The rate of reaction between hydriodic acid and chloric acid affords a good practical example of catalysis. If the equation for the reaction is:

$$6HI + HClO_3 \rightarrow HCl + 3H_2O + 3I_2,$$

then we may write:

$$-\frac{dC}{dt} = k \,.\, [HI]^6 \,.\, [HClO_3],$$

which will reduce to the equation for a monomolecular reaction if a suitable excess of hydriodic acid be used.

In practice, solutions of suitable concentration of sodium or potassium iodide and of potassium chlorate may be prepared, and mixed in required proportions, and a suitable quantity of acid of known concentration added to start the reaction when required. The acid should contain a small known concentration of an iron salt which acts as catalyst. With an excess of iodide, the experimental figures give a monomolecular reaction constant which, if the initial concentrations of all the other substances added are kept constant, is proportional to the concentration of iron. The reaction is followed by titrating portions of the reaction mixture from time to time with a thiosulphate solution. The reaction seems to be very sensitive to traces of impurities, so that if ordinary pure materials are used, it is best to make up a quantity of each solution required sufficient for all the experiments that are to be carried out. Thus a series of numbered flasks might each have 50 c.c. of N iodide solution and 50 c.c. of N/20 potassium chlorate solution, and be left to

take up the temperature of the thermostat. Then, to start the reaction, add to the first a mixture of 50 c.c. of 2N sulphuric acid and 20 c.c. of water; to the second, the same quantity of sulphuric acid, 19 c.c. of water and 1 c.c. of a N/10 ferrous sulphate solution; to the third the same amount of sulphuric acid, and, say, 5 c.c. of the ferrous sulphate solution and 15 c.c. of water, and so on. In this way, the initial concentrations of all the substances will be the same, except that of the catalyst, i.e. ferrous ion. There is plenty of scope for variation in this problem in investigating the effect on the reaction velocity of altering the concentrations of the various reactants (see Bray, *Journ. Phys. Chem.* 7, 92 (1903); *J.C.S.*, A. ii, 275 (1903)). Actually, experimental evidence points to the reaction

$$ClO_3' + I' + 2H\cdot = HClO_2 + HIO$$

as being the slow reaction which controls the reaction velocity.

334. OXALIC AND CHROMIC ACIDS[1]

W. H. Barrett.

Equal volumes of one-fifth normal oxalic and one-hundredth normal chromic acid are brought to 25° C. in a thermostat and mixed. Twenty c.c. of the reaction mixture are removed at measured time intervals, and run into a mixture of 10 c.c. of potassium iodide solution (about N/10) and dilute hydrochloric acid. The iodine liberated is titrated with N/60 thiosulphate solution. The concentration of the chromic acid is, of course, proportional to the number of c.c. of thiosulphate used. The experiment is then repeated with equal volumes of N/10 oxalic and N/100 chromic acid. It will be observed that in both experiments the concentration of the oxalic is very much greater than that of the chromic acid, so that it may be regarded as remaining constant. The experimental figures will be found to give a constant k, where

[1] Dhar, *J.C.S.*, 111, 708 (1917).

$k = \frac{1}{t} \log \frac{a}{a - x}$, the first titration being taken as a ($t = 0$) and subsequent titrations as $(a - x)$, showing that the reaction is monomolecular with respect to the chromic acid.

In practice, values ranging from 2·5 to 3 are obtained for m, the number of molecules of oxalic acid reacting with one of chromic acid, indicating that the reaction between oxalic and chromic acids may be represented by the equation :

$$3H_2C_2O_4 + H_2Cr_2O_7 \rightarrow Cr_2O_3 + 6CO_2 + 4H_2O.$$

Interesting examples of the effect of catalysts on this reaction and an examination of other reactions which proceed with a reasonable velocity and can be easily followed will also be found in the original paper referred to on p. 120.

RESISTANCE OF ELECTROLYTES

335. AN OSCILLATOR SUITABLE FOR CONDUCTIVITY WORK

S. R. Humby

The use of a small induction coil or a buzzer for producing an alternating current in measuring the conductivity of solutions has a serious disadvantage. The sound produced by the vibrator is often so loud that the "silent point" can hardly be detected if the buzzer is in the same

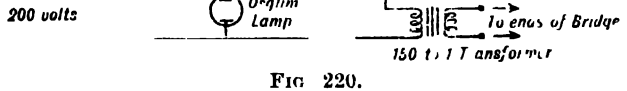


FIG. 220.

room as the experimenter. A neon tube can be made to produce electrical oscillations of musical frequency by means of a simple circuit, and the whole apparatus can be built up at a very small cost for use where 200–240-volt mains are available.

An "Osglim" lamp (General Electric Company) is joined in series with a high resistance of about ·5 megohm, and connected to the mains. Across the lamp is placed a fixed condenser of capacity ·001–·003 microfarad and the high-resistance windings of a radio transformer. The low-resistance coil of the transformer is joined to the ends of the Kohlrausch bridge.

It can be shown that such a circuit has a time period given by $T = C.R.k$, where k is a constant for a given lamp used at a fixed voltage. The values of C and R given are chosen to produce a musical frequency rather over 1,000 per second. R can be made by a pencil line ruled on ebonite or slate, or it can be bought from a dealer in wireless apparatus. C is an ordinary parallel plate condenser.

With a home-made resistance, the apparatus can easily be adjusted by connecting a telephone receiver across the transformer and gradually decreasing the resistance from an infinite value by rubbing a hard pencil lightly along a scratch cut in a small piece of ebonite.

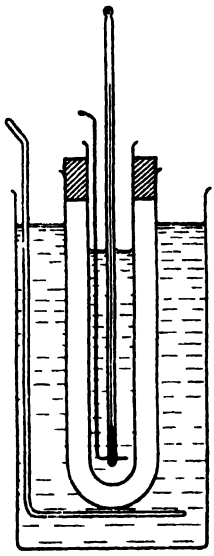


Fig. 221.

The zero point is very sharply defined on a metre bridge, the sound being readily detected in the laboratory for a movement of 1 mm. on either side of the point.

Another form of oscillator is described in experiment 96, Part I.

SOLUBILITY AND SOLUBILITY PRODUCT

336. A SOLUBILITY DETERMINATION

W. H. Barrett

The apparatus consists of two large concentric boiling tubes with an air space between, placed in a

beaker of water which can be slowly heated. Known weights of water and solute are placed in the inner tube, and the temperature is slowly raised till the last small crystal is dissolving (rounded edges). The temperature is then lowered till the small crystal is growing (sharp edges). The mean of these two temperatures (which should not be more than 1°-2° apart) gives the temperature at which solution is just saturated.

337. SOLUBILITY OF SODIUM CHLORIDE IN HYDROGEN CHLORIDE

W. H. Barrett

For a solubility problem which can be carried out fairly quickly, the effect of hydrochloric acid on the solubility of sodium chloride is suitable.

Five c.c. of a saturated salt solution are placed in a test-tube and hydrochloric acid added, a drop at a time, until a precipitate of salt just begins to form. Then the experiment is repeated with a mixture of 5 c.c. of the salt solution and 1 c.c. of water, then with 5 c.c. of the salt solution and 2 c.c. of water, and so on.

While adding the hydrochloric acid, there is a temporarily large concentration of hydrochloric acid in the neighbourhood of the drop as it falls into the solution, so that there is little fear of supersaturation. If the determinations are made carefully, so that very little salt is precipitated, it will be possible to calculate rough values for the solubility of salt in solutions of hydrochloric acid of varying concentrations, provided that the original concentrations of the salt and hydrochloric acid solutions are given. Or, alternatively, the students may also be required to find the concentrations of these solutions, given, say, tenth normal solution of silver nitrate, and see if they will make a suitable dilution of the stronger solutions before titration.

338. SOLUBILITY OF LEAD CHLORIDE IN HYDROGEN CHLORIDE

W. H. Barrett

An alternative problem to the above consists of preparing a number of dilute solutions of hydrochloric acid, ranging from, say, N/5 to N/100, and shaking some of each solution in a corked flask with some carefully prepared lead chloride, and then titrating specimens from each flask, after allowing time for the attainment of equilibrium, with silver nitrate and a thiocyanate solution. If the original strength of the hydrochloric acid was known, it will then be possible to determine the concentration of the lead chloride, and thus examine the effect of hydrochloric acid on the solubility of lead chloride. Since lead chloride is comparatively soluble, the principle of the solubility product will not be strictly applicable, but it is instructive to compare the figures obtained by experiment with those predicted by an application of this principle.

339. A CLOSED SOLUBILITY CURVE

W. H. Barrett

It is well known that for a pair of liquids the mutual solubility relations are, in general, represented by a closed curve; but the commonly quoted instance of nicotine in water is not suitable for elementary work. Butyl alcohol may, however, be obtained at a reasonable price, and with hydrochloric acid of suitable concentration, gives a closed solubility curve with both upper and lower critical solubility temperatures lying between 0° and 100° C. The solubility of the butyl alcohol is very sensitive to impurities (Orton, *J.C.S.*, 116, 1194 (1919)), and therefore it is necessary to use portions of the same specimen of butyl alcohol for a whole series of determinations if consistent results are desired. The strength of

the hydrochloric acid should be in the neighbourhood of four times normal; if the acid is too strong, the liquids are miscible in all proportions, and if the acid is too weak, the upper and lower critical temperatures move above 100° and below 0° C. respectively, but a few preliminary experiments will show the correct strength of acid to use. The simplest method for making the determinations is to fit a small flask with a cork and thermometer. A very small groove in the cork obviates too great increase of pressure inside the flask on heating. Some butyl alcohol, say, 20 c.c., is measured into the flask, and 1 c.c. of acid run in from a burette. If this mixture remains homogeneous at all temperatures, another 1 c.c. of the acid is added, and so on. Soon enough acid will have been added to form a mixture which will separate into two layers at some temperature. This mixture is heated until it is homogeneous, and allowed to cool slowly. At the solubility point striæ will appear in the liquid, and it will then rapidly turn cloudy. The liquid is then cooled down until it again turns clear, and it is then allowed to warm slowly. Again a solubility point will be obtained when the liquid begins to turn cloudy. In this manner the two points are obtained for a given solution. Then a small measured addition of hydrochloric acid is made and the two solubility points are again determined. Proceeding in this manner, the complete closed solubility curve can be traced out. If a number of students are doing the problem, it is more interesting if some small variation in the strength of the hydrochloric acid can be made so that each student uses a solution of different strength (making the variation within small limits and preparing all the solutions from the same strong solution by dilution), when it will be evident, on plotting all the results on one sheet of graph paper, that with increasing strength of hydrochloric acid, the closed curve gradually contracts and finally disappears.

340. QUANTITATIVE VERIFICATION OF SOLUBILITY PRODUCT

F. G. Mee

Many experiments are available for the qualitative demonstration of the existence of the solubility product, but quantitative experiments are less common. Most substances that are used are not fully ionised in saturated solution, so that in these cases, a knowledge of their degree of ionisation at the particular concentration would be required. The substance slaked lime, $Ca(OH)_2$, however, is a strong base, and its saturated solution at ordinary temperature is barely N/20 in strength, so that it is safe to assume that it is completely ionised. It is easy to find the amount of lime in a solution by titration, and therefore to find the solubility product.

Lime should have a smaller solubility in a solution of caustic soda than in water, and it is the object of this experiment to verify that the decrease of solubility that occurs is that which would be expected from the application of the Law of Mass Action to the ionic equilibrium

$$Ca(OH)_2 \rightleftarrows Ca^{\cdot\cdot} + 2OH'.$$

If we provide extra OH' ions from some other source —NaOH in this case—the concentration of $Ca^{\cdot\cdot}$ ions should decrease in such a way that the product of it and the square of the concentration of OH' ions remains a constant, if the solution is saturated.

To verify this, solutions of lime are made up in (1) water, (2) N/40 soda, (3) N/20 soda, (4) N/10 soda. The soda should be as free as possible from carbonate, and the solutions can be made by adding a quantity of slaked lime to each of the soda solutions and allowing to stand, with shaking at intervals. Each of these solutions is titrated with N/10 HCl, which will, in each case, give a measure of the total OH' concentration present. The OH' concentration due to the soda is known, assuming this to be fully ionised also. Subtraction will yield the

concentration of OH′ due to dissolved lime, and the concentration of $Ca^{\cdot\cdot}$ is exactly half of this. This titration will thus give us all we require to calculate the solubility product.

A typical set of results is the following:

Twenty c.c. of each of the four solutions were titrated with N/10 HCl, using phenolphthalein indicator, with results shown in the second column of the table.

Solution in	Titration. c.c.	Ionic concentrations in gm ions/litre.				
		Total OH′ present.	OH′ due to soda.	OH′ due to lime.	$Ca^{\cdot\cdot}$	$Ca^{\cdot\cdot} \times (OH')^2$.
Water	9·5	·0475	--	·0475	·0237	$5{\cdot}4\ 10^{-5}$
N/40 soda	11·6	·058	·025	·033	·0165	5·6
N/20 soda	14·2	071	·050	·021	·0105	5·3 ...
N/10 soda	21·8	·1090	·100	·0090	·0045	5·4

The constancy of the product is striking. The effect of decreasing the solubility due to the NaOH appears during the experiment, before the detailed calculation is made. Lime in water gave a titration 9·5 c.c.; N/20 soda alone would give 10 c.c. Yet lime in N/20 soda gives but 14·2 c.c., showing that the solubility has been reduced to about one-half by the presence of soda at this concentration. The result with N/10 soda cannot be expected to be very accurate, since at this concentration the lime contributes so very little to the total OH′. If more than four results are desired, they should therefore be taken with soda solutions between the above values, and not stronger than N/10.

THERMAL DISSOCIATION

341. INFLUENCE OF PRESSURE ON THE DISSOCIATION OF CALCIUM CARBONATE

E. J. Sumner

A small crystal of Iceland spar (chosen for its transparency) is placed in the bulb of a hard glass tube arranged

so that carbon dioxide, in a continuous stream, may be passed over it while being heated. The glass below the crystal may now be raised to a dull red heat without any sign of decomposition in the crystal; even after heating for 10 minutes, it remains quite transparent on cooling.

Air is now allowed to pass up the tube while the same flame is playing round the bulb, and a gradual change in the crystal is soon evident. It becomes opaque on cooling, and a drop of water placed on the cool mass gives further evidence of the presence of quicklime.

The temperature of the crystal during the first heating in carbon dioxide should not, of course, be allowed to rise above that at which the dissociation pressure of the carbon dioxide is one atmosphere.

342. A DEMONSTRATION OF DISSOCIATION PRESSURE

W. J. Gale

The apparatus admits of the ready demonstration of dissociation in such a gas as the brown oxide of nitrogen, the breaking down of the molecules with rise of temperature being visualised by the increased pressure shown by a mercury gauge.

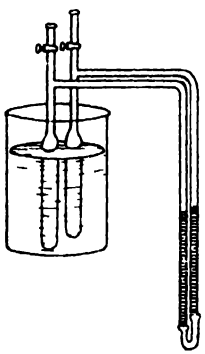


FIG. 222.

Two strong test-tubes are fitted with corks through which passes one limb of a T-piece. Of the remaining two limbs of the T-piece, one communicates by a short piece of pressure tubing with a U-tube mercury gauge, whilst the other is closed by a short piece of tubing with screw clip.

The two tubes are arranged side by side in a water bath (if a glass vessel is used the colour change can be followed at the same time), and one is filled with the mixed gases obtained by

heating a little finely powdered, and carefully dried, lead nitrate.

(Alternatively, a few drops of liquid nitrogen tetroxide are poured into the tube and the clip (or stop-cock) closed when the gas has ceased to issue from the tube.)

The screw clips are then used to equalise the pressure, and the water is heated. The apparatus is similar to a " differential air thermometer " in form, and the ordinary increase of pressure at constant volume for a rise of temperature is obviously compensated ; hence the additional pressure in the nitrogen peroxide tube is at once made manifest.

It is absolutely essential that the whole apparatus and contents should be dry if the pressure is to be maintained in a steady manner. A liquid has not yet been found that can be used in the gauge in the place of mercury, which is rapidly attacked by moist nitrogen peroxide. If the apparatus is to be permanently fixed up, it must be made entirely of glass ; a piece of 12-mm. tubing is pulled out and joined on to a tube with glass stop-cock, into which is sealed (between stop-cock and wide portion) a tube, about 30 cm. long, bent at right angles at about 10 cm. from the insertion. Broken 50-c c. pipettes lend themselves to this purpose. Two such pieces of apparatus are made, and the gauge tubes are joined by a piece of pressure tubing, as shown in the sketch. Mercury that has been carefully purified and dried is used for the gauge, and into one bulb a few drops of liquefied tetroxide are admitted via the stop cock. The rest of the proceedings for adjustment and use is obvious.

THERMOSTATS

343. AN ELECTRICALLY-HEATED AND CONTROLLED THERMOSTAT

D. Ll. Hammick

(1) *The Tank* —If possible, this should be fitted with a glass front ; a small cistern or water tank is, however, a

satisfactory substitute. It should be painted inside with white paint, and given an outside covering of some material of low thermal conductivity, such as felt or wood. It is filled with water sterilised with phenol.

(2) *Stirrer.*—Electrically driven by a small motor. It is possible, however, to effect quite efficient stirring by means of a stream of air bubbles.

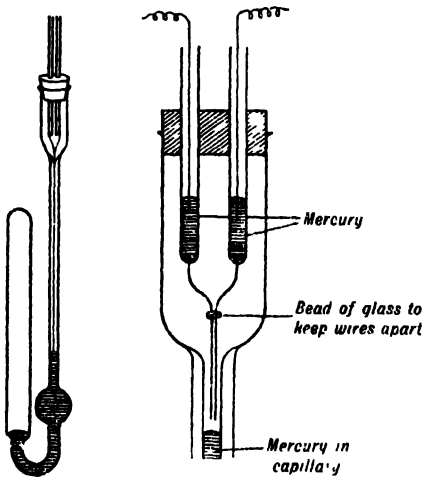


FIG. 223.

(3) *Heater.* — This may be either a long metal filament lamp such as is used in electric radiators and immersed in the tank, or may be made by cementing (Faraday's wax, etc.) an ordinary carbon-filament lamp on to the end of a long glass tube. Wire leads are soldered on to the lamp terminals and pass up through the glass tube.

(4) *Regulator.*—Temperature is kept constant as the result of the expansion and contraction of a volume of toluene contained in a glass bulb (Fig. 223). As the toluene gets hot and expands, a thread of mercury in the capillary tube (1·5–2·0-mm. bore) is pushed up and makes connection between two fine platinum wires ; a current thereupon activates a small relay, and cuts out the heating lamp. As the toluene cools and contracts, the mercury thread falls, contact is broken between the platinum wires, and the relay re-establishes the heating circuit.

(5) *Diagram of Electrical Connections.*—Three circuits in parallel are required : one to run the stirring motor, the second to supply the heating lamp, and the third to

pass through a lamp and small rheostat from which a small E.M.F. can be "tapped off" through a circuit in

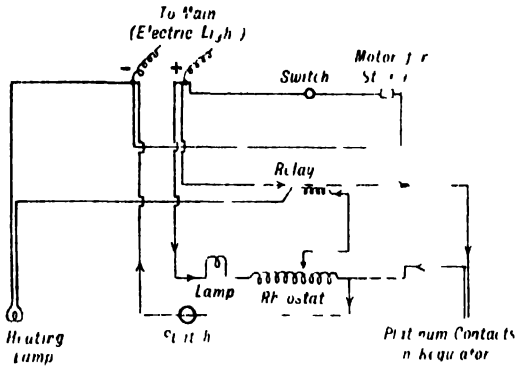


FIG. 224.

parallel, to provide the activating current for working the relay when connection is established in the regulator.

344. A CHEAP BUT EFFICIENT THERMOSTAT

R. B Rawsthorn

The tank is a biscuit tin, seams soldered, inside painted and enamelled white. A rotating vane, made from Meccano parts, is attached to a spindle, which rotates in a small bracket, fastened by screw nuts and solder to one

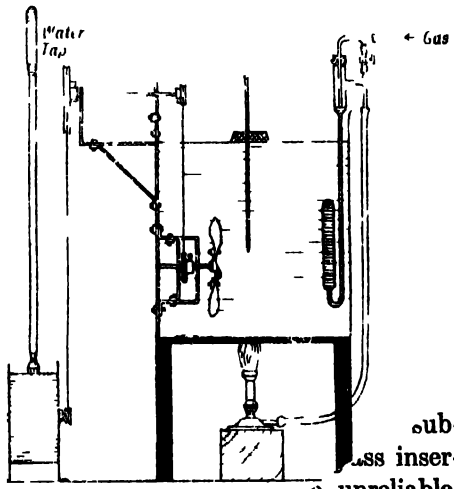


FIG. 225.

sub-
ss inser-
e unreliable.

side. The vane is rotated by a string moving round wheels, one on vane spindle and the other attached to a spindle which is fixed in a bracket on the top edge of the tank. This spindle is in its turn rotated by a small water turbine.

The latter was made by one of the boys from a fruit tin, pieces of tin, and Meccano parts, and is a most efficient instrument; of course a small motor would equally well serve the purpose.

Temperature is regulated by the usual form of toluene gas regulator, connected to a Fletcher Bunsen with gauze cap.

It is possible to keep the temperature steady within half a degree for quite long periods—the instrument has been kept working for a full week with admirable results.

345. A SIMPLE THERMOSTAT

T. E. W. Browne

A bulb, A, about 1½ in in diameter, is blown on a short length of glass tubing, which is then bent at right angles and sealed on to a thistle-funnel, C. A second thistle-funnel, B, is then sealed into this portion as shown. The stem of this second funnel should be about 2 in. shorter than that of C, and the bends should be adjusted until the apparatus will stand firmly. Convenient dimensions are: C, vertical portion, 6½ in.; B, vertical portion, 4½ in. A cork, fitted with delivery and supply pipes, is inserted into B, care being taken that it is the inlet pipe and not the pipe to the Bunsen which is closed by the rising mercury, otherwise the tip is likely to be clogged up by a small bead of mercury after the level has fallen; the pressure of the gas supply, however, is usually sufficient to clear this away.

The mode of action will be evident from the diagram.

(5) [illegible] the apparatus for a definite temperature, empty in parallel [illegible] the mercury and replace the thermostat in the second to [illegible]ing the necessary connections (Fig. 226).

As soon as the required temperature is reached, add mercury through the open thistle-funnel until the gas supply is just cut off. Final adjustment may be made by carefully moving the inlet pipe in or out of the cork.

The air holes of the Bunsen should be closed just before the thermostat comes into action for the first time,

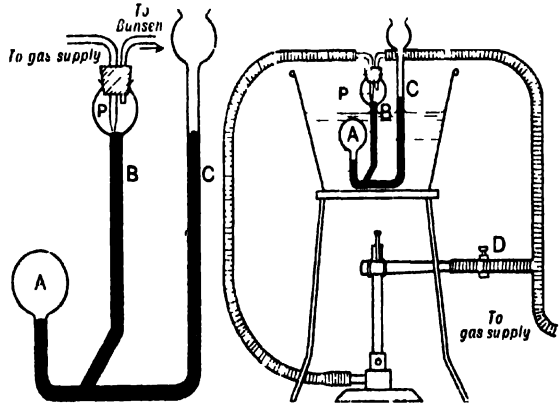


FIG. 226

otherwise "burning back" will occur, but, once adjusted, the air supply may be safely left for hours if the Bunsen is shielded from draughts.

Some form of constant feed is essential if the bath is at all small and is to be left for any length of time, for even at 30° C. evaporation is quite rapid, and the apparatus requires so little attention that replenishment of water is apt to be forgotten.

346. LOWERING OF VAPOUR PRESSURE

D. Ll. Hammick

Two glass tubes, A, B, are made as shown (Fig. 227). The diameter of the wide tube is about ½ in., and of the inserted quill tubing about 5 mm. It is possible to substitute rubber connections at *i*, *i*, for blown-glass insertions; they are, however, very apt to be unreliable.

Pure solvent is introduced as shown into A and a solution in B. Glass tubing, *c*, *d*, *c*, is then sealed on as in Fig. 227*a*; the side tube is narrowed at *e*, and connected to an efficient water suction pump. The liquid in A and B boils under diminished pressure, and its vapour sweeps all air out of the apparatus. The bend at *d* serves as a trap to prevent solution that sometimes boils out of B from making its way into A. When boiling has occurred in both A and B,

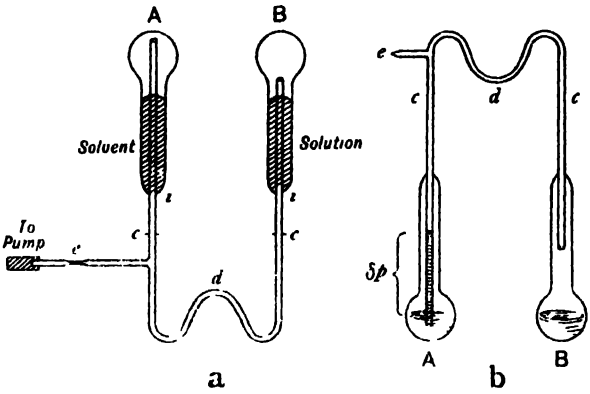


FIG. 227.

the constriction at *e* is sealed off with a small flame and the apparatus inverted, as in Fig. 227*b*. We then have a vapour pressure in A (pure solvent) greater than the vapour pressure in B (solution). A column of liquid, δp, is therefore forced up the narrow tube in A until the hydrostatic pressure of the column is equal to the difference in vapour pressure between solvent and solution.

By measuring the height of the column of liquid in A, the lowering of vapour pressure can be used to determine the molecular weight of the dissolved substance in B. Such measurements should be made with the apparatus immersed in a thermostat; thus obtained they yield values for the molecular weight to within 5 per cent. A very convenient solvent is methyl alcohol; suitable

solutes are picric acid, acetanilide, etc., in about 5 per cent. solution. The abnormality of electrolytes can be illustrated with 2N sodium hydroxide.

VOLUMETRIC ANALYSIS

347. MODIFIED METHYL ORANGE

Oxford, 1921

Methyl orange solution, when mixed with a few drops of the "light filter" methylene blue, affords an indicator very superior to the unadulterated liquor, because alkali produces strong green, acid orange-red, and so-called "neutrality" a pale-grey tint. The proportion of methylene blue is readily found by trial. Titrations, especially by gas light, are rendered easier.

348. MODIFIED METHYL ORANGE [1]

K. C. D. Hickman and R. P. Linstead

The uncertainty in using methyl orange as compared with phenolphthalein is well known; with a two-colour indicator like the former, the colour change occurs in a previously saturated colour and the eye does not readily perceive it; with a single-colour indicator, the change occurs in a colourless or neutral-coloured liquid and its first appearance is easily perceptible.

Spectrum photographs of methyl orange in alkaline solution show that the absorption band practically obscures the blue end of the spectrum and extends to about 5100 Å.U., which is in the green; the transmitted light is made up of red, orange-yellow, some green and a trace of blue, of which yellow is usually the brightest. During neutralisation, the absorption band shifts towards the red, and when the solution is acid, a little more blue passes and the green is obscured. The yellow-orange still

[1] *Journ. Chem. Soc.*, 1922, Vol. 121, p. 2052.

remains, and the spectrum photographs make it clear that the screening off of the orange-yellow would be an advantage.

The dye xylene cyanole F.F. has an absorption band in the yellow-orange; consequently, when this is mixed with methyl orange, the colours transmitted in alkaline solution are extreme red, green and a trace of blue; but the luminosity of the red and the blue being small compared with that of the green, the solution appears green. During neutralisation, the absorption band of methyl orange shifts towards the red, cutting off the green; hence, when the solution is acid, the colour is a mixture of blue and red, or magenta. But between these two extremes, there is a period when the amounts of red, green and blue transmitted are visually equal, so that the solution appears white or neutral grey. The colour change is therefore green–neutral grey–magenta.

The indicator is made up by dissolving 1 part of methyl orange and 1·4 part of cyanole in 500 parts of 50 per cent. alcohol, and to get the best results these proportions must be used. Two or three drops are sufficient for the titration, and the grey neutral point corresponds with a hydrogen-ion concentration of $p\mathrm{H} = 3{\cdot}8$. In a separate series of experiments, it was shown that the neutral grey corresponds precisely with the end point usually taken for methyl orange alone.

The modified methyl-orange indicator can be used for all titrations in which methyl orange is commonly employed.

349. BASICITY OF CITRIC ACID

R. G. Durrant

With decinormal citric acid, it can be shown that the acid appears to be monobasic when methyl orange is used, and tribasic when litmus is used as the indicator of neutrality

350. DETERMINATION OF AMMONIA IN AMMONIUM SALTS, ETC.

Birmingham

The usual method of heating a weighed amount of the ammonium salt with excess of strong caustic soda solution in a large flask connected by a safety bulb and vertical small condenser was followed ; but instead of passing the evolved ammonia into standard acid, it was passed into a large beaker containing distilled water. (Actually there is a wide glass tube dipping just below the surface of the water, and fixed by means of a rubber cork to the bottom of the condenser tube.)

The novelty of the method lies in the fact that the ammonia, as it comes over, is neutralised at once by the addition of standard acid from a burette. The indicator employed is bromophenol blue (neutral colour green ; acid yellow ; alkaline blue). Before starting the experiment, standard acid is run into the distilled water in the large beaker, until the neutral tint (green) is indicated, when a few drops of bromophenol blue are present. This precaution is necessary, since with this indicator water does not appear to be neutral.

As soon as the experiment is started and ammonia is being evolved, standard acid is run in from the burette, and the colour of the indicator is kept as near to the neutral tint as possible. In this way, accurate results can be obtained, and the evolved ammonia is dealt with at once.

The indicator can be prepared as follows : Dissolve a weighed amount of bromophenol blue in absolute alcohol (using as little as possible of the latter). Then dilute with distilled water so as to make a solution of ·04 per cent. concentration.

351. DICHROMATE TITRATION WITH AN INSIDE INDICATOR

W. H. Barrett

Ferrous salts can be titrated by a dichromate solution and *vice versa* by using diphenylamine dissolved in concentrated sulphuric acid as an indicator, in the presence of phosphoric acid, which is necessary presumably to reduce the concentration of ferric ion. The titration must be carried out in acid solution, either sulphuric or hydrochloric acid being added to the ferrous solution until it is at least normal with respect to the acid.

The indicator solution is made by dissolving 0·2 gram of diphenylamine in 100 c.c. of concentrated sulphuric acid, and the phosphoric acid is made by diluting syrupy phosphoric acid with twice its volume of water.

For use with N/10 solutions which have been made acid with sulphuric acid, 4 drops of the indicator and about 5 c.c. of the phosphoric acid are added to every 25 c.c. of the ferrous solution to be titrated. On adding the dichromate solution, the green colour deepens, especially towards the end, and at the end-point one drop of dichromate solution in excess changes the colour to blue.

Diphenylamine may also be used as an indicator with permanganate solutions, and the appearance of the blue colour is said to be much more sensitive than the appearance of a visible permanganate colour when working with very dilute solution (N/100 or less).

The temperature of the liquid to be titrated is of importance when using diphenylamine. The liquid should not be below room temperature, nor should it be hot; a temperature of 18°–20° C. appears to be best for maximum sensitiveness.

352. ADSORPTION INDICATORS

W. H. Barrett

An entirely new type of indicator depends on adsorption on the surface of colloid particles. When a chloride

solution, for example, is being titrated with silver nitrate, so long as chloride ions are in excess, some of them, at any rate, are adsorbed on the surface of the silver chloride. When the point of equivalence is reached, there are no longer any chloride ions adsorbed on the surface of the silver chloride particles, and when one drop in excess of the silver nitrate has been added, silver ions begin to be adsorbed on the colloidal particles of silver chloride.

If traces of fluorescein are present in the solution, the anions of this dye-stuff are not adsorbed by the colloid particles of silver chloride so long as chloride ions are present, since the chloride ions are preferentially adsorbed, but when all the chloride ions have been removed by titration, the fluorescein ions are then adsorbed and change colour so soon as silver ions also are adsorbed on the chloride particles. The change of colour is therefore visible so soon as there is a small excess of silver ions (one drop of the silver nitrate solution in excess). The particular adsorption indicator chosen depends on the halide ion which is being titrated. Eosin is an admirable indicator for bromide, iodide and thiocyanate ions, but not for chloride ions, since the eosin may be more strongly adsorbed than the chloride ion. When the chloride ion is being titrated, fluorescein must be used. The use of these indicators is due to Fajans.

For the titration of *neutral* N/10 solutions, 5 drops of indicator solution (0·2 gram fluorescein in 100 c.c. of alcohol) should be added to every 25 c.c. of chloride solution, and the point of equivalence is indicated by the sudden appearance of a reddish colour *on the precipitate*. Experience will help in recognising when the equivalence point is approaching by a change in the state of aggregation of the precipitate. Fluorescein can only be used in neutral solutions and in solutions which are not too dilute. Further details of this determination are given by Kolthoft.

Eosin is used for the titration of bromide, iodide and thiocyanate ions. With eosin the solution may be as

strong as N/10 with nitric acid, the end-point is sharper than with fluorescein and more dilute solutions may be titrated (up to N/1,000).

For 25 c.c. of N/10 solution, 5 drops of eosin solution (0·5 gram eosin sodium in 100 c.c. water) are used, and at the point of equivalence the precipitate suddenly becomes red on the addition of one drop in excess of the silver nitrate solution. When more dilute solutions are being titrated, the quantity of indicator may be slightly reduced.

The use of adsorption indicators is only in its infancy.

BIOLOGY

ANIMAL PHYSIOLOGY

353. THE DIAPHRAGM IN BREATHING—DISSECTION

T. H. Taylor and A. S. Barker

THE action of the diaphragm in mammalian respiration affords opportunity to introduce a physiological episode into a course of physics when atmospheric pressure is the subject in hand. It is also an important topic in connection with the hygiene of breathing.

1. Obtain from a poulterer a snared or trapped rabbit with the stomach, liver and diaphragm intact.

2. Pin the body to a dissecting board with ventral surface upwards.

3. Remove the skin from ventral surface of thorax and neck.

4. Having opened the abdomen, ligature the œsophagus, cut it across between ligature and stomach, and remove stomach. Cut away the liver, leaving a small piece attached to the diaphragm, which must not be damaged in doing so.

5. Examine the abdominal surface of the diaphragm, noticing the concave form and tense (taut) condition. Confirm by pressing with the moistened finger-tip. The lungs can be seen through the diaphragm.

6. Dissect aside the muscles of the breast and expose the breastbone and ribs.

7. Counting from the neck, identify on the left side the 4th and 5th ribs, and pierce with the scalpel point the flesh between them.

8. Examine the diaphragm again, and observe that the

left half has now lost its tension and become flabby (pull with forceps).

9. Repeat on the right side paragraphs 7 and 8, and notice that the whole of the diaphragm has now collapsed, the inference being that when the air is allowed to enter both sides of the thorax, the tense condition of the diaphragm is permanently lost, atmospheric pressure being now the same on its thoracic surface as on its abdominal.

10. *Contents of Thorax.*—With scissors cut across the breastbone between the 1st and 2nd, and between the 4th and 5th ribs, and across the 2nd and 3rd and 4th ribs on each side about ¾ in. from the middle line. Remove the piece of thoracic wall thus separated, first detaching the underlying membranes from the inner surface. Examine the large space (thoracic cavity) now exposed, and with finger-tip and forceps explore the contents and their relations to one another, viz. the heart, lungs, membranes and thoracic surface of the diaphragm.

11. Enlarge the opening by cutting away more of the ribs and flesh, taking care not to pierce the lungs or damage the diaphragm. Further examine the parts and observe that a median membrane completely divides the thoracic cavity into two parts (right and left pleural cavities). Demonstrate by pulling lungs forward and diaphragm backwards.

12. In the neck expose the windpipe (trachea) by turning aside the muscles stretching from the 1st rib to the head. Remove front end of breastbone and ventral portion of first pair of ribs. Make a short longitudinal incision in the ventral (upper) wall of the trachea, insert a glass tube (blowpipe) and blow into the lungs. Notice that the lungs quickly respond and become distended, and also that when the pipe is removed they at once collapse. The experiment shows that the lung tissue is elastic, that the covering is imperforate and air-tight, and that when the thorax is opened the lungs become, practically speaking, collapsed.

13. Note, however, that the dissection does not show

in what state the lungs are in the uninjured thorax—a blank which can be filled in only from indirect evidence (see "The Diaphragm in Breathing, Experimental Evidence," experiment 3).

14. *Removal of the Heart.*—Observe the transparent membrane (pericardium) loosely surrounding the heart; slit the ventral wall of the pericardium by a median incision and press back the two halves. Cut across the blood-vessels entering the heart and remove it. With damp sponge clean up escaped blood.

15. In the median membranous partition between the two pleural cavities, notice the large blood-vessel (posterior vena cava) passing towards the heart (removed), and right and left nerves passing to the diaphragm.

16. Push the lungs to one side of the cavity and expose the œsophagus and, dorsal to the œsophagus, the aorta, lying on the backbone. Trace them backwards to the diaphragm.

17. Examine the abdominal surface of the diaphragm and observe the posterior vena cava attached to the remains of the liver. Notice also the ligatured end of the œsophagus.

18. With the finger-tip locate in the middle line the bony ventral processes of the vertebræ lying between the kidneys; remove the latter and the adrenal bodies. Carefully clear away the fatty tissue in this region and expose the aorta.

19. Note in detail the attachment of the diaphragm (1) to the breastbone and ribs; (2) to the muscles of the back; and (3) in the middle line to the ventral vertebral processes. In order to demonstrate these attachments, the diaphragm should be pressed backwards by finger-tip or glass rod. It will be seen that the dorsal margin of the diaphragm, i.e. the part attached to the vertebræ, is very muscular, forming the so-called "pillars."

20. *Removal of the Diaphragm.*—Cut across the ribs to which the diaphragm is attached. With scalpel point

carefully sever the attachment of the diaphragm to the œsophagus and the median membrane and to the muscles of the back; and cut across the "pillars" close to their attachment to the vertebral processes. Sponge the dissecting-board and spread out the excised diaphragm with its abdominal surface upwards. Snip away the attached pieces of rib and liver, and note (1) the central tendinous area; (2) the aperture of the vena cava and of the œsophagus; and (3) the peripheral muscles (including the "pillars"). A drawing should be made showing the shape and parts of the diaphragm.

21. Cut across the trachea in the neck and separate it, together with the bronchi and lungs, from the underlying tissues, care being taken not to lacerate the lungs against the cut ends of the ribs.

22. Repeat with blowpipe the inflation of the lungs, noticing again their expansibility and elasticity.

23. Immerse lungs in water and note that they float. Cut across one or more of the lobes and note the escape of air bubbles when the lung, although practically speaking collapsed, is compressed.

24. Returning to the thorax, note that the ribs are attached to the backbone in such a manner that the cut ends can be readily swung forwards. Observe, however, that they are strongly curved, and of such a character as to prevent their being either straightened or further bent. Thus the framework of the thoracic wall is sufficiently rigid to prevent the wall from yielding when the diaphragm contracts. When the ribs are swung forwards by the thoracic muscles, it will be evident that the thoracic cavity is enlarged.

Note.—The space between the lungs and the thoracic wall (the pleural cavities) is filled, not with air, but with watery fluid (lymph). This can be demonstrated by (1) inserting a pipette into the thorax and drawing up some of the fluid; and (2) observing that when the thorax is opened under water, no air is seen to escape.

354. THE DIAPHRAGM IN BREATHING—EXPERIMENTAL

T. H. Taylor and A. S. Barker

Two questions are suggested by the dissection (No. 353): (1) Why is the diaphragm when at rest tense and thrust forwards into the thorax? and (2) Why do the lungs, although composed of elastic substance, become inflated with air when we breathe?

The following experiments will throw some light on these questions.

EXPERIMENT 1.—TO SHOW THAT AIR TENDS TO FILL ANY EMPTY SPACE TO WHICH IT HAS ACCESS

Material Required.—Separating funnel fitted with rubber stopper pierced with a hole; stop-cock and tube; rubber balloon; filter pump and pressure tubing.

The funnel (Fig. 228) is filled with water and securely connected to the pump by pressure tubing. The stop-cocked tube is passed through the rubber stopper, and the balloon tied to the lower end of the tube. When the stopper is placed in the neck of the funnel and the empty balloon arranged inside, the upper stop-cock is closed. The lower one is now opened and the pump started, its action being to draw water from the funnel. As the level of the water in the funnel sinks, the balloon comes to lie in an empty space (vacuum), the only entrance to which is through the tube. The lower tap is now closed,

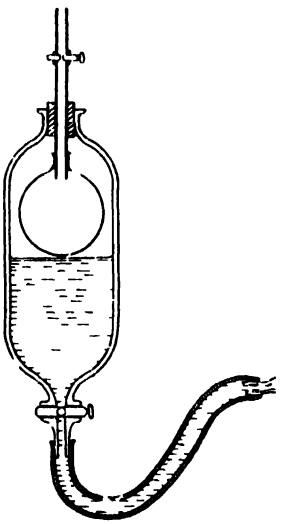


FIG. 228

and the upper one opened. Immediately the upper tap is opened the balloon becomes inflated, almost completely filling the space between the water and the top of the funnel—a result due, it is plain, to the weight of the atmosphere.

Note.—To get the best result, the balloon, before being tied to the tube, should be emptied of air under water. Since the passage through the upper tap is narrow, instead of turning the tap on, it is better to draw it out of the tube. To show the actual passage of air into the balloon, the free end of the upper stop-cock should be connected to a glass vessel filled with smoke.

Experiment 2.—To show the Effect of pulling the Diaphragm Backwards

Obtain a rabbit as before. Expose trachea and insert the nozzle of blowpipe to which is connected a glass U-tube. The U-tube is fixed to a board covered with white paper, and is partly filled with a coloured fluid, e.g. dilute red ink. When the two columns of ink have come to rest and are equal in height, the levels should be marked on the paper (levels 1 and 1*a*, Fig. 229).

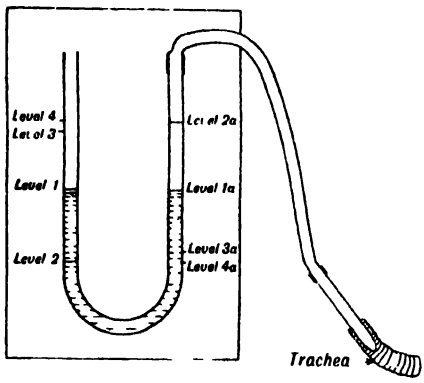


Fig. 229.

Pull the diaphragm gently back and notice that the fluid in the tube moves towards the thorax (levels 2 and 2*a*). Release the diaphragm and note that the fluid returns to its former position (1 and 1*a*).

The experiment indicates that pulling the diaphragm back causes air to flow into the lungs, and that when the diaphragm is released air flows out.

Note.—A stop-cock inserted somewhere in the rubber tube is a useful addition.

Experiment 3

Using the same apparatus and noting again the levels 1 and 1*a*, pierce the left thoracic wall and notice that the fluid in the tube moves away from the lungs. Mark on the paper the two new levels (3 and 3*a*). Pierce the other (right) side of the thorax, again marking the levels (4 and 4*a*).

The experiment shows that, during the intervals of breathing when the lungs are in the position of rest, they contain a relatively large amount of air. The experiment also shows that when the thorax is pierced, a considerable part of the air is expelled by the elastic contraction of the lung tissue ; and that for the maximum amount of air to be expelled, both sides of the thorax have to be pierced, the inference being that the two pleural cavities are completely separated from each other. (See p. 142 (11).)

Note.—An examination of the levels 3 and 4 shows that more air leaves the lungs after the first puncture of the thorax (left side) than after the second (right side), even although the smaller (left) lung collapses first. The reason for this difference seems to be that when the first puncture is made, not only does the lung on that side (left) collapse, but also that on the other side (right) as well, although not to the same extent. This partial contraction of the right lung at the same time as the total contraction of the left is rendered possible by the flexible condition of the median membrane lying between the two pleural cavities.

Experiment 4.—Working Model to illustrate the Action of the Diaphragm

Material Required.—Bell-jar with tubulure and flange rubber bung to fit tubulure and pierced with two holes

a rubber balloon ; sheet of patching rubber ; glass rod and glass tube ; plasticine and bicycle valve.

The valve is fixed into the centre of the rubber sheet, as in a bicycle tube. A layer of plasticine is pressed on the outer face of the bell-jar immediately above the flange. The rubber sheet is stretched across the mouth of the jar and firmly tied upon the bed of plasticine. The glass tube is passed through the bung, and carries the balloon tied to its inner end.

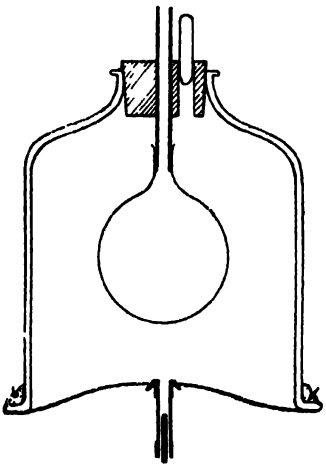


Fig. 230.

As thus arranged, the bell-jar represents the thorax, the balloon the lungs, and the rubber sheet the diaphragm. The bicycle valve merely serves as a convenient form of handle with which to grasp the rubber diaphragm.

(*a*) To complete the model, the diaphragm is pushed into the bell-jar, and the glass rod is then inserted into the vacant hole in the bung, the air inside the jar being thereby shut off from the air outside. The diaphragm, on being released, assumes a convex form towards the lung, and the lung becomes partly inflated, both being mutually held in a state of equilibrium and prevented from collapsing (see Fig. 230). The condition of the model now represents the thorax in the position of rest, and helps to answer question 1, viz. why the diaphragm is thrust forwards into the thorax.

(*b*) When the rubber diaphragm is pulled downwards, the cavity of the bell-jar (thoracic cavity) is enlarged, and since there is an opening to the outside through the glass tube (trachea), air tends to enter and occupy the additional space in the jar, but is prevented by the balloon

(lung) which closes the tube inside. The balloon, however, being elastic and extensible, readily becomes expanded and fills the space thus formed. This part of the experiment indicates the reason why air flows into the lungs.

(c) When the diaphragm is released, the balloon contracts, owing to the elasticity of its walls, and the parts of the model assume again the position of equilibrium, the pull of the balloon again balancing that of the diaphragm.

Note.—In the above model, the space between the balloon and sides of the bell-jar is filled with air. If a small bell-jar is used, this space can be filled with water (cf. the lymph in thoracic cavity); and since, when the balloon is surrounded by water, it practically adheres to the bell-jar, the action of the model is improved and resembles the natural process more closely.

355. ANATOMICAL VALVES

T. H. Taylor and L. R. Johnson

To demonstrate the action of valves in circulatory systems, the sheep's heart forms a very convenient type for study. The butcher should be instructed to leave attached to the heart as great a length as possible of the aorta and pulmonary artery. There is no lack of published accounts if a guide to the dissection is required, one of the best being that given in Foster and Shore's *Physiology for Beginners* (Macmillan).

The auricles and ventricles, the afferent and efferent blood-vessels and the valves having been examined, the action of the valves can then be discussed and analysed by means of models. A rubber bulb, compressed by hand and then released, serves to represent the contraction and expansion of the ventricles; glass tubing fitted to the bulb the blood-vessels. For valves, pieces of fine silk cloth are suitable, but better results can sometimes be obtained by using pieces of fresh gut (e.g. rabbit's intes-

tine) flattened or in tubular form. Valves of this description work best in water, but their action can be shown in air if the air is impregnated with smoke or vapour ; or the air can be made to deflect things, e.g. a candle flame.

It is well to start by showing the result of simply pumping the bulb, and then to show what effect the valves have.

Experiment 1.--The model[1] (Fig. 231) consists of a rubber bulb fitted to a glass tube, the free end of which dips into a vessel of coloured water. The rise and fall of the water caused by pumping the bulb can be shown either by having the bulb above the tube (upside down) or below it (right way up). When the model is the right way up and the bulb filled with water, movement of the water begins as soon as the bulb is compressed ; whereas when the model is upside down, some of the contained air has first to be driven out. We can speak of this alternate rise and fall of the water as a movement of *oscillation*.

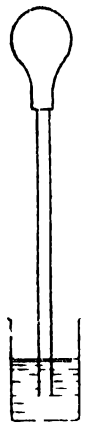


Fig 231

Experiment 2. – The model (Fig. 232) consists of a bulb possessing two apertures and carrying two tubes which are bent in such a way that, when the bulb is held horizontally, each dips below into a separate vessel of water. Pumping the bulb produces two oscillating columns moving up and down together. The water should not be allowed to rise into the bulb, except when it is desired to show that two different liquids can be mixed together by this means.

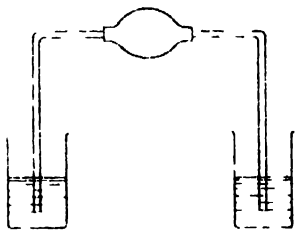


Fig 232.

Experiment 3.—The model (Fig. 233) is the same as the last, except that a valve, made of a piece of gut, is fitted

[1] The figures show the models in the position of rest.

over and tied to the end of one of the tubes. If we start with the bulb in the compressed position and dip the tubes into water, we notice that when the bulb is released, water rises in the open tube, but not in the one that is fitted with gut, the reason being that the sides of the gut are flexible and become pressed together (sucked together) as the bulb expands. Vigorous pumping forces water past the bulb and out through the valve, and if continued, will transfer practically all the water to the other vessel. Moreover, since the valve acts both in air and in water, this happens whether the latter vessel is empty or full to begin with. This experiment shows that even by introducing one valve, the movement of oscillation is altered and becomes a mixed movement made up of an oscillating column and a current flowing in one direction from one vessel to the other. It is obvious that if both vessels are connected at their base by a common tube, the water drawn away by the pump would be replaced by water flowing in from the other side. The streaming of a given volume of water always in one direction can be described as a movement of circulation, and the experiment in the form just mentioned serves to set up a circulation; but there is a flaw present in that some of the water drawn up is forced back when the bulb is compressed. The movement therefore is more correctly described as an *imperfect circulation.*

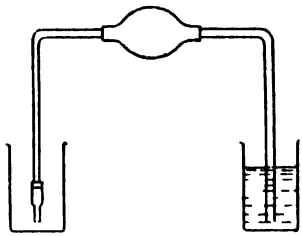


FIG. 233.

Experiment 4.—This experiment is designed to show that water drawn up as in experiment 3 can be prevented from flowing back. By removing this flaw, the experiment should produce a true *circulation.* The method is simply to employ a second valve and attach it to the other tube. It is difficult, however, to fix the new valve to the tube when model 233 is employed. It is better to pin

the valves flap-wise to corks which have been bored for the purpose. The two corks with their valves are then placed in the ends of the glass tubes and the tubes into the bulb. Whether such a model will work depends upon the direction in which the valves open and close. If both valves open inwards, water can be drawn in but cannot be pumped out again. If one valve opens inwards and the other outwards, water can be drawn in at one side and pumped out at the other. The direction of flow, which can be

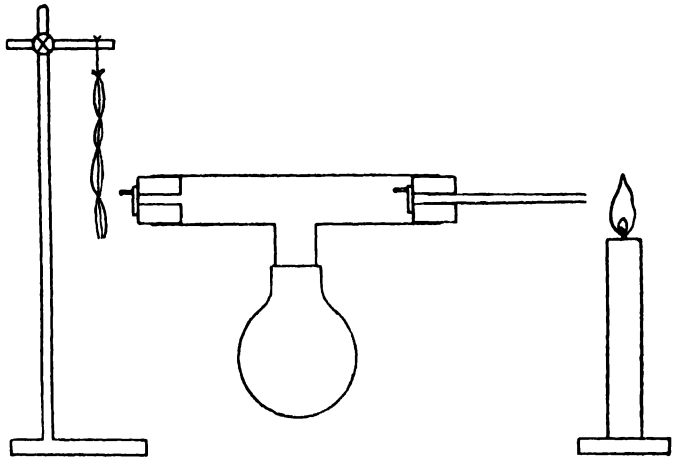


FIG. 234.

indicated by adding drops of coloured water to the current, it is important to note, is the same as the direction in which the valves move when they open. If the vessel or tank required is not available, the experiment can be shown in air (see Fig. 234). A three-way glass tube is fitted with a rubber bulb, such as is used for motor horns, and the corks with their valves attached are fitted into the two opposite ends. For the ingoing valve at the entrance a piece of gut does best; for the exit valve a piece of silk fabric can be used, but to be efficient it should be kept wet. To keep the silk wet, a ring of thick blotting-paper is placed between it and the cork, and wetted from time to time. For showing the movement

of air from a distance, ammonium chloride vapour is useful; or a candle flame can be placed at the inlet, and light silk threads at the outlet. To lessen the scorching effect of the candle, a glass tube is added, one end of which is fitted into the cork and the other held in or near the flame. Both the valves should be wetted from time to time.

From these models we learn that the direction in which the blood flows through the heart is the same as that in which the valves open. Thus, simply inspecting the valves is sufficient to indicate how the blood flows. For instance, if the semilunars opened into the ventricles and the ventricular valves into the auricles, the flow of blood in such a heart would be reversed.

The efficiency of the semilunar valves can be shown by excising the pulmonary artery and tying it to a glass tube 2 or 3 ft. long. Water is poured in at the top, but it is better to draw it up through the valves from below, preferably by mouth.

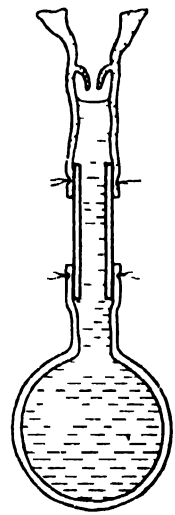


Fig. 235.

To show the action of these valves, the excised artery is tied to a short glass tube of suitable size, the end with the valves (proximal end) projecting free. The tube is held vertically and is fitted below into a motor bulb filled with water. Pumping the bulb moves the water up and down, thereby alternately pressing the valves together and drawing them apart.

The action of the mitral valves is shown by means of a similar pump tied into the aorta between the semilunar valves of which the tube projects into the ventricle. The outer wall of the auricle should first be removed. A similar method can be adopted for the tricuspid valves.

The use of the tendinous cords in restraining the valves can be shown by cutting the cords across and observing

how, when the bulb is compressed, the valves flap back into the auricle. The cords can be readily cut by passing the scalpel through the opening in the auricular wall and then under the cords, i.e. between them and the ventricular wall. The demonstration shows best when the heart is under water.

356. THE EXCRETION OF CARBON DIOXIDE BY AQUATIC ANIMALS

Cambridge, 1923

To about 5 c.c of water, in a boiling tube, add 3 or 4 drops of an indicator (·04 per cent. cresol red). To A in Fig. 236 attach an aspirator, and draw air in at B until equilibrium is established and there is a certain concentration of hydrogen ions in C. Ascertain the degree of concentration by comparing the colour of C with that of the liquids in a set of similar tubes containing "standard solutions." Insert the fish, or other small aquatic animal; note the time; replace the cork.

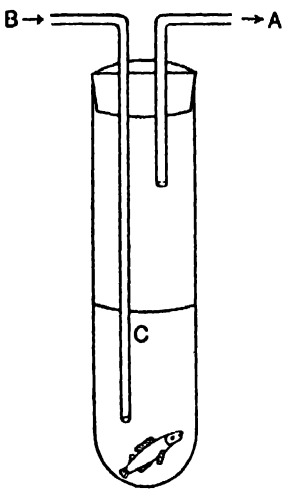


FIG. 236.

As the fish or other animal excretes carbon dioxide, the hydrogen-ion concentration changes, the colour of the indicator changes, and when a sufficiently marked contrast has been obtained (about 5–10 mins.), the new position on the scale of standard solutions and the time are again determined. The method is very delicate and can be used for a great variety of aquatic creatures.

CULTURE MEDIA

The following are recommended for pure cultures of such fungi as Mucor, Penicillium, Aspergillus, Phytophthora, Pythium, etc.

357. BROWN'S SYNTHETIC MEDIUM

Cambridge, 1929

Asparagin	2·00 grams
Glucose	2·00 ,,
Pot. phos.	1·25 ,,
Mag. sulph.	0·75 ,,
Starch (not always added)	10·00 ,,
Agar-agar	20·00 ,,
Distilled water	1,000 c.c.

358. DOX'S NUTRIENT AGAR

Pot. acid phos.	1·00 grams
Pot. chloride	0·50 ,,
Ferrous sulphate	0·01 ,,
Sod. nitrate	2·00 ,,
Cane sugar	15·00 ,,
Mag. sulph.	0·50 ,,
Agar-agar	20·00 ,,
Distilled water	1,000 c.c.

359. POTATO EXTRACT AGAR

This is the filtered extract obtained by boiling 200 grams of potatoes in 1 litre of water, and adding 2 per cent. agar-agar to solidify.

360. BEERWORT AGAR

This is simply made of the proportion of 50 per cent. beerwort to 2 per cent. agar-agar.

All these media must be sterilised in an autoclave for 20 minutes at 126° C.

Phytophthora should be grown on potato agar; while Pythium does well on this or on Brown's medium.

361. WATER CULTURE EXPERIMENTS

Mary A. Johnstone

Water culture experiments have for their object the determination of the elements essential to the plant as food material, and how the plant is affected by the lack of given elements from its diet. The principle followed is to cultivate plants in water solutions of known chemical constitution. One solution is normal and contains all the elements supposed to be necessary; growth in this is compared with that in a series of other solutions from each of which, in turn, there is omitted a single element. The directions for carrying out the experiments which are set out here are those which have been actually tested in our laboratories. Quite probably there are equivalents which will prove equally satisfactory.

Culture Solutions [1]

A solution (normal):

Distilled water	1,000 c.c.
Potassium nitrate	1·0 gram
Magnesium sulphate	0·25 ,,
Ferrous phosphate	0·5 ,,
Calcium sulphate	0·25 ,,
Sodium chloride	0·5 ,,

B solution. *Cut out nitrogen* by substituting potassium chloride for potassium nitrate.

C solution. *Cut out potassium* by substituting calcium nitrate for potassium nitrate.

D solution. *Cut out magnesium* by leaving out magnesium sulphate: there is sulphur left in the calcium sulphate.

E solution. *Cut out sulphur* by using calcium nitrate and

[1] Mary A. Johnstone, *Matriculation Botany*, p. 132.

magnesium chloride instead of calcium sulphate and magnesium sulphate.

F solution. *Cut out phosphorus* by substituting ferric chloride (a trace) for ferrous phosphate.

G solution. *Cut out calcium* by leaving out calcium sulphate: sulphur remains in the magnesium sulphate.

H solution. *Cut out iron* by substituting calcium phosphate for ferrous phosphate.

I solution. *Sodium and chlorine* can be cut out together by leaving out sodium chloride.

J solution. *Cut out everything.* Use as control a jar of distilled water.

Preparation of Culture Solutions

Prepare, in accordance with the prescriptions set out above, the solutions which it is intended to test. Be particular to use the purest salts procurable and to sterilise the vessels used. Use distilled water, of course. Store the solutions—about 2 litres of each, in stoppered glass bottles. Be careful about labelling, fixing two to each bottle as a precautionary measure.

Preparation of Culture Jars

Use glass jars having a capacity of at least 1 litre. The types of jars and their fitments here described have been found most satisfactory. The actual vessels were inexpensive stock obtained from the household department of a general store and had been intended for kitchen storage purposes; they possessed ground-glass rims, were wide-mouthed, and 17 cm. high.

Corks, 1·5 cm. deep and 8 cm. in diameter, were made to order, to fit the jars exactly; they were coated with paraffin wax. From the centre of each cork a circular section, 2·5 cm. (C–D, Fig. 237), was cut. From this removable cork a small central core was bored out, leaving a cylindrical cavity for the reception of the slender

plant stem. The small cork was cut vertically and diametrically along the line C–D; the two halves when separated allowing easy insertion of the specimen.

Immediately before setting up the experiment, sterilise the culture bottles by washing them out with dilute sulphuric acid; rinse out thoroughly with distilled water. The corks should also be cleansed. Label each jar as it is filled; attach the chief label as a narrow strip along the lower edge of the jar, where it will not interfere with viewing or photographing the growth within the jar; for safety, an additional identification mark may be fixed on the base of the jar.

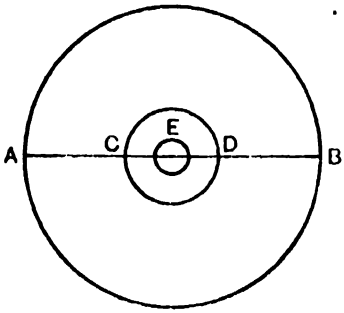


FIG. 237

Each jar is enclosed in a cover which will entirely exclude the light. This is made of a two-fold thickness of the heaviest quality of black Italian cloth. Cut a strip of this of such dimensions that, when doubled, and sewn end to end to form a bottomless bag, it fits neatly round the jar, and is deep enough to reach from the base of the vessel well over the cork. Through a slot at the top run a double drawstring. Attach to the cover a label which corresponds with the label on the jar; any particular culture can then be selected for inspection without removing other covers.

SELECTION OF PLANT MATERIAL

Strong seedlings or slender herbaceous cuttings may be used—the latter seem more suitable for school conditions. Cuttings of *Tradescantia* have been found excellent, but various other plants of quick growth will serve. Seedlings should have the minimum of seed-reserve food

attached to them wheat is preferable to maize; sunflower may be tried.

The utmost care must be taken that the specimens chosen are equal in size and vigour and in leaf area; variegated leaves of *Tradescantia* must not be included. Before estimating leaf-surface, remove any lower leaves which would hinder fitting into the jar. If the plants from which cuttings are taken have not been reared in school, those obtained from tradesmen should be kept under observation for a week or so—they have been known to fall off badly owing to transference from greenhouse temperatures. Seedlings should be grown in sand or on damp muslin, and the roots gently washed clean before putting them into the solutions. The axis of the plant must not fit so tightly into the cork that there is no room for growth in thickness.

Take the branch cuttings with care; make a sharp, clean cut; by cutting just below a node, root-formation from the node is encouraged. An additional precaution may be taken if thought desirable: to make sure that the vascular tissue does not get air-blocked, perform the cutting under water. All operations, especially with seedlings, must be carried out as quickly and delicately as possible.

April, in a northern city, has been found to be the most suitable month in which to set up culture experiments. Conditions of light and temperature will be guides to this.

Setting up the Cultures

Everything being in readiness, fill each of the labelled jars with its appropriate solution. The jars must not be filled quite to the top; the amount of air-filled space left above the liquid cannot be exactly specified, since it depends on the size of the plant used; it is an advantage to have as much air enclosed as possible.

Prepare the cuttings, or seedlings, as already specified; insert them between the halves of the smaller cork; adjust

them so that the seedling roots, or the lowest node of the cutting, is well covered by the liquid. Slip on the cloth cover from the base of the jar upwards; use the draw-strings to draw it up rather loosely round the plant stem. It can be slipped off very easily when the contents of the jar are to be examined. Sometimes a little cotton wool is packed round the stem.

After-care of Cultures

Place the jars side by side in positions such that they get similar treatment in the matters of light, heat, etc.; the window ledges in the school laboratory have proved quite suitable, the south windows being avoided during the first ten days.

Directions are usually given for aerating and for renewing the culture solutions. For example, the cork may be pierced to allow of the insertion of a glass tube through which air can be blown into the liquid, the cork stopper being meanwhile raised a little. Some workers change the solution once, or oftener. For school experiments, which are not generally carried on so long as those in more advanced work, but are intended to demonstrate principles of cultural needs, it has not been found necessary to take either of these steps. For the replenishing of the air supply to the roots, the space above the solution seems to yield a sufficient supply by diffusion. Again, if plenty of the culture solution is used (the litre appears to be enough for a moderate-sized branch), there is no need to change it completely. As the level in the jar is lowered, owing to absorption and transpiration, additional solution from the stock jar can be added as is required. One of the aims kept to the front in the experiment should be to disturb the plants as little as possible.

Records

These, one need not insist, must be full and exact; made at regular intervals, even if results are negative.

Amongst points to be noted are: growth in length of shoot, number and size of leaves, colour, buds, general strength, variations in rate of growth throughout period of observation. Of great importance is it to watch the progress of root development; this is made easy by the facility with which the cloth covering can be removed and replaced.

CULTURES

362. MICRO-AQUARIUM TECHNIQUE

Monica Taylor, S.N.D.

One of the first essentials to be secured is that the micro-aquaria should be stored in some place where they will be left quite undisturbed throughout the year. Vacations, "spring" cleaning, and such necessary events, must not be allowed to cut short the term of existence of any given aquarium. The biological laboratory, then, must contain a permanent receptacle for aquaria which, while not actually being used, nevertheless provide valuable material for future use. In our laboratory, we have a wooden stand, provided with shelves (3 ft. × 9 in.) like a bookcase without back and front portions, which serves admirably for storing aquaria, and which does not monopolise much space.

The micro-aquaria to be used for cultures can consist of almost anything from a jam-pot, or a sweet bottle, to a glass pneumatic trough. To safeguard the supply of Daphnia, we have a large wooden "washing" tub (3 ft. diameter, 1 ft. height) on a small roof near the laboratory for breeding this animal. This is provided with pabulum, consisting of leaves and other decaying organic matter, or suspensions of Horlick's Malted Milk. The Daphnia breed quite readily in this pond, and since we require our Hydra in October and are therefore using large quantities of Daphnia to feed them during that month, the copious supplies in the tub are very useful. Apart

from this auxiliary aquarium, the rest of the micro-aquaria are housed in the laboratory.

363. RAISING OF ANIMALS IN CULTURES

J. T. Saunders

Much of the technique is rule-of-thumb, but recent work has shown the reasons for keeping to these rules in order to ensure success. Even at its best, success never attends all our efforts, and if 50 per cent. of the cultures succeed, we may congratulate ourselves.

Scrupulous cleanliness is essential. Unwanted forms appear in the cultures in vast numbers, and prevent the required forms from breeding.

Tap water may be used for all these cultures, but we must not forget that tap water varies considerably in different districts. Many Protozoa appear to be injured or destroyed by the water becoming only slightly alkaline (*p*H 8·3- 8·7). It will therefore sometimes be necessary, in districts where the water is "hard," to use rain water in order to prevent the cultures becoming too alkaline when exposed to the atmosphere.

I have tried to see how long the cultures which I have described will exist if left unattended. None of them will flourish without careful attention, and only Paramecium, Colpidium and Daphnia cultures will continue to exist over a period as long as the school summer holidays without any attention at all. The level of the liquid in the hay infusion will, if left for this length of time, fall, through evaporation, almost to the bottom of the jar, but on refilling and adding a little fresh hay, the culture will revive again in a week or ten days. The cultures in the Zoological Laboratory at Cambridge are kept going simply by refilling from time to time and adding a little fresh hay now and then. Refilling with water reduces the numbers of the animals in the culture for a short time, but they reappear again in from seven to fourteen days.

Daphnia, if left unattended, will survive to a certain

limited extent. I left 120 bottles, each containing one animal, for eight weeks. At the end of this time, sixteen of the bottles contained living specimens. These, as observation showed, had existed without breeding. On feeding them regularly once more with the weak solution of rotten egg, they regained their vitality and power of reproduction.

364. CULTURE OF AMŒBA

Monica Taylor, S.N.D.

To procure inoculation material, secure quantities of the rich organic detritus that collects on the surface of the mud at the bottom of slow-moving streams. The diatom collecting apparatus is useful, but, failing this, an ordinary collecting tube (wide test tube with flat bottom) may be used to skim off the mud, the collector kneeling down by the side of the stream for this purpose and placing the successive skimmings into a collecting jar of some description.

Bring the mud thus gathered into the laboratory and allow it to settle for a few hours at least. Then, having procured a glass pipette (a fountain pen filler will serve), run it over the surface of the mud, and place the contents thus pipetted up into a solid watchglass. If Amœbæ have been included in the "catch," they will appear as whitish specks when the contents of the watchglass are viewed over a dark background with a strong lens. The Amœbæ thus collected by a systematic examination of the "catch" should next be put into a micro-aquarium in which boiled wheat grains[1] (twenty-two wheat grains to a litre of water) and water (about 50 c.c. to begin with, this amount being eventually increased to the capacity of the aquarium) have been added. In the pipette along with the Amœbæ will be countless other organisms in

[1] The wheat can easily be obtained from a seed merchant. A quantity, e.g. ½ lb., can be boiled at one time and when thoroughly dry, can be stored in a glass stoppered bottle for future use. The boiling is simply to kill the embryo in the wheat "seed," which otherwise might germinate, and need only be carried on for about five minutes.

"association" with them, so that the micro-aquarium started for the cultivation of Amœbæ has been necessarily stocked with other organisms, either in the active or the "spore" condition.

Several expeditions into the country may be necessary before sufficient inoculation material has been secured. In the meantime the pond gatherings should be stored. They will be useful for all sorts of purposes.

Another method of securing Amœbæ is to collect large quantities of pond weeds, Spirogyra, Vaucheria, bladder worts, etc., etc., and to wash the gatherings out by squeezing them in water, finally retaining the washings, in which Amœbæ may sometimes be found. The discarded weeds, when left to macerate, frequently supply inoculation material for rotifers, and may thus be usefully employed for obtaining the latter.[1]

The best month of the year for starting cultures of *Amœba proteus* is July. The Amœbæ are increasing rapidly by fission in August, September, October and November. At the end of November many proceed to produce encysted young, and during the early spring months the young Amœbæ are growing up.

The quickest method of inoculating a culture is to subculture from an already existing and firmly established Amœbæ culture. Obviously it is essential to keep everything used for the aquaria quite free from acids and stains; a very slight change in the *p*H of the water of an aquarium may have disastrous consequences. Obviously, too, a pipette used for crustacean cultures must not be used, without having been sterilised, for protozoan cultures. It is always safest to run boiling water through a pipette before it is used for taking up liquid from an aquarium. If hot water is not available, then some killing fluid (acetic acid) should be used for sterilising it, care being taken to wash this off quite completely.

As already indicated, boiled wheat grains form an

[1] Gatherings containing Cyprids may be rejected as useless. These Crustaceans quickly produce a desert.

excellent pabulum for Amœbæ cultures. The minute organisms, flagellates, ciliates, which are carried over from the pond water along with the Amœbæ when the inoculation is being performed, flourish in the infusion of wheat in water, and, as a rule, multiply with greater rapidity than do the Amœbæ, which are slow growers. A luxuriant crop of organisms which will serve as food for the Amœbæ is soon established. It is obvious that the success of an Amœbæ culture, given the requisite Amœbæ for the inoculation purposes, ultimately depends on the value and variety and number of the food organisms included in the initial inoculation. These food organisms can of course be supplemented from other sources besides that in which the Amœbæ were actually captured.

Three months after starting a culture, the Amœbæ will be ready for class purposes. After that the culture will always contain some, but will not be so good for adults at certain months of the year. Fresh wheat should be added about every two months, the amount depending wholly on the number of inhabitants present in the aquarium. An examination of a few drops of the aquarium water, after the whole has been gently stirred up, will give a rough idea of the conditions. If adult Amœbæ are numerous, more wheat is required. About ten grains per litre of liquid present in the aquarium is a rough measure. Over-feeding can quickly be detected by smelling the water. The easiest method of counteracting the effects of over-feeding is to divide the implicated culture between two aquaria, filling up each half with fresh water.

365. CULTURE OF AMŒBA

J. T. Saunders

Amœbæ do not lend themselves readily to simple experiments, and their culture is not so easy as that of ciliates and flagellates. Cultures often flourish and then, a few days before they are required for use, die off in a most

annoying fashion. They are best cultured in small flat-bottomed glass dishes (jars used for preserved ox tongues are excellent for this purpose). The method is to place a few boiled wheat grains in a dish, filled with water to a depth of not more than ½ in., and to keep this covered to prevent evaporation. The dishes are kept in a room screened from sunlight. The bottom of the dish becomes covered with a growth of green algæ, and it is in this that the Amœbæ flourish. If the Amœbæ are put in the dish a few days after the wheat grains, when these have begun to decompose, they will often flourish abundantly and may be seen in thousands at the bottom of the dish. These flourishing cultures often die out quite suddenly, so that constant sub-cultivation is necessary in the same way as with Spirostomum (see p. 173).

Although I have made no experiments to test this, I suspect that the Amœbæ are killed by the water becoming too alkaline. In order to prevent this high alkalinity, it is necessary to use " soft " water, or rain water collected from a clean roof. It is not possible to adopt the method of checking the rise in alkalinity that is used in the Spirostomum cultures, for this leads to the oxygen content of the water falling too low. Amœbæ suffer from lack of aeration, and it is therefore essential to use flat dishes, covered with only a shallow layer of water. Additional aeration by blowing air through the cultures every three or four days with a pipette is highly beneficial. The difficulty of Amœba cultures is to keep the alkalinity low and the aeration high. The only obvious way of doing this is to use " soft " water.

366. CULTURE OF COLPIDIUM AND PARAMECIUM

J. T. Saunders

Perhaps the easiest of all animals to rear are the ciliates, Colpidium and Paramecium. The procedure is

of the simplest. A small bell-jar, holding about two litres, whose opening is about two-thirds of its height, is filled with tap water. Into this tap water is placed a handful of hay; the culture is then set aside in a window, not too exposed to the sun, and left uncovered for three to six weeks. After about a fortnight or three weeks, depending on the temperature, Colpidia appear on the surface, to be followed later by Paramecia. As far as we know at present, the course of events in the culture is this. Substances dissolve out from the hay into the water, and these provide a medium for the growth of bacteria. The bacteria flourish, and the water becomes highly charged with carbon dioxide and acid in reaction (*p*H 4·0–6·0—depending on the amount of alkali present in the added tap water). It is also devoid of oxygen, and there is a scum covering the surface which prevents the escape of carbon dioxide, keeps the water acid, and so apparently allows the bacteria to flourish and to pave the way for the appearance of Colpidium. If the scum be continually broken, the protozoa rarely appear in any number. It is therefore necessary to leave the vessel uncovered. If covered with a plate of glass, the drops of moisture condensing on the glass fall back into the water and keep destroying the scum. With the bowl uncovered the evaporation is considerable, but we can check this to a great extent by leaving a good deal of the hay sticking out of the water.

Paramecium and Colpidium, which nearly always appear together in hay infusions, are sometimes confused. Colpidium is much smaller than Paramecium, is more transparent and always appears first in the infusion before Paramecia are to be seen. Later, Colpidia and Paramecia appear together, the Paramecia gradually increasing in numbers until, in the latest stages, the Paramecia predominate and only a few Colpidia are to be found. In these old infusions, Paramecia may often be seen lustering together to form whitish masses, easily visible to the naked eye. These clumps are usually to be

seen near the surface of the water, at the edges of the vessel, or attached to hay stems just below the surface. On sucking up these whitish clumps with a pipette, it will be seen that they are almost solid masses of Paramecia.

367. CULTURE OF DAPHNIA

J. T. Saunders

Of the smaller Crustacea, Daphnia is very easily cultivated. The method is to place a single animal in a small bottle, holding about 300–500 c.c. and half filled with water. Cover the mouth of the bottle with a watch-glass to prevent evaporation. Food is provided by breaking an egg into a pint of water, shaking it up and allowing it to go rotten (preferably in a stoppered vessel). A few drops of this rotten-egg mixture are added to water, making it cloudy. Of this cloudy water, one drop added daily to the water in which the Daphnia are living serves for sufficient food. Under these conditions, the Daphnia produce a brood of 10–20 young every 10–14 days. These broods cannot be left crowded in the jars; they must be separated, and sub-cultured. The surplus stock, however, serves to supply food for another useful animal, Hydra.

368. CULTURE OF DAPHNIA

Monica Taylor, S.N.D.

Material to start Daphnia cultures is easily obtained from duck ponds and other stagnant pools. Sweet bottles, battery jars, etc., serve admirably for their cultivation. It is well to have three or four aquaria, so that while one is being depleted of Daphnia to supply Hydra with food, the others may be recuperating. Plenty of food and a warm temperature (60° F. and upwards) are necessary if constant supplies are required. All sorts of pabula may be employed, e.g. decomposing leaves,

cheese water, water in which pieces of fish have been macerated. A very convenient substance is Horlick's Malted Milk. A gram of this substance mixed to a paste in boiling water and then diluted to a bulk of, say, 50 c.c. can be added to an aquarium, well stocked with Daphnia and of a capacity of five or more litres, every week.

Daphnia are very susceptible to change of environment. Wild specimens must be gently acclimatised, and fed sparingly at first. Tap water should never be used in making sub-cultures. "Soil" water is harmless. Since Horlick's Malted Milk tends to make the water acid, it is advisable to add a few c.c. of normal NaOH when making up the pabulum. The *p*H of a Daphnia culture should always be at least 7. (Test this with litmus paper.) From time to time all the Daphnia in a culture should be strained off and put into a new supply of pond or "soil" water, otherwise the accumulation of metabolic products causes the onset of "winter" egg production and parthenogenetic reproduction slacks off.

When Daphnia are not required, they may be allowed to die down. The débris from the bottom of such "quiescent" aquaria may be used to restart the culture when it is necessary to do so. Freshly mixed Horlick's Malted Milk diluted with water, together with some of the débris from an old culture, will yield Daphnia in a short time. The Daphnia frequently reappear in the "quiescent" aquarium after a period of time without the application of any technique, the winter eggs having given rise to a new generation.

The tub containing Daphnia by means of which the laboratory cultures are supplemented also serves as a breeding-ground for the harlequin fly, the larva of which affords a useful type for study.

369. CULTURE OF EUGLENA

Monica Taylor, S.N.D.

An opportunity of securing inoculation material for the cultivation of this organism is often to be found,

especially during spring, in muddy puddles that occur in roads frequented by cattle. A puddle which is vividly green in colour is almost sure to contain Euglena. A good pabulum for this organism is canary guano, or any other fertiliser used by gardeners. The canary guano (about a tablespoonful to a gallon of water) should be boiled and allowed to settle, the supernatant fluid being transferred to the aquarium as an organic nutrient fluid for the Euglenæ. These flourish well in wheat or bean water and in infusions of cow-dung. A non-flagellate form, which exhibits euglenoid movement very perfectly, is a frequent inhabitant of some Amœba cultures. When the Euglenæ are required for class purposes, some of the material from the stock should be taken out, mixed with fresh water and pabulum, and put into a warm place in a strong light, when the creatures become active. It is interesting to contrast the rôle of the pabulum in the case of Euglena and the other micro-organisms mentioned in Nos. 364, 368, 370, 372. In the former, apart from its main nutrition, which is holophytic, the pabulum, i.e. the organic fluid, is actually absorbed by the animal. In the case of the other micro-organisms, the pabulum simply serves to supply nutrient material for those other organisms in the culture that serve as prey for the principal animal, i.e. the animal that is being reared.

370. CULTURE OF HYDRA

Monica Taylor, S.N.D.

Material for starting cultures of brown Hydra can usually be secured by hunting in the ponds. This, having once been obtained, can be stored in miniature Hydra ponds, which can then be used as the initial source for the intensive cultivation of Hydra that precedes the day on which this coelenterate is to be studied by the pupils. Some weeks before this day, the length of time to be regulated by the number of specimens required, a new brown Hydra should be transferred to a small

aquarium, with a quantity of the pond water in which they have been living. A good substitute for natural pond water can be readily made by mixing a handful of soil with a litre of tap water and allowing the whole to settle. The supernatant fluid can be used with impunity in all those cases where pond water is necessary. Tap water without any admixture of pond water is fatal to all organisms. When the Hydra have fastened themselves well to the substratum and have become settled down and accustomed to their new surroundings, which process sometimes requires about twenty-four hours, they must be fed with Daphnia, or any other available crustacean. The Daphnia are collected in sufficiently large numbers by straining the water from a Daphnia aquarium through a small fishing-net. A convenient form of net can be made by forming its framework out of a piece of the cane used in basket-making, and fastening to this some coarse canvas material. (Mr. Smith, of the Plymouth Biological Station, is quite willing to supply small quantities of the material used at the Station for nets of various kinds.) Hydra thus fed constantly with Daphnia begin to bud rapidly, and in a few weeks a veritable forest of individuals will be the result. The water from these should be poured off and replaced by pond, or artificially made pond water, from time to time during this period of intensive cultivation, as the excreta tend to make the water foul, or failing that, to favour a crop of ciliates which are detrimental. A pond for storing Hydra is made by placing a certain amount of pond débris on the bottom of an aquarium (say, to a depth of $\frac{1}{2}$ in.) and stocking this with cyprid and Daphnia eggs, etc., pond water, and pabulum, e.g. decaying leaves or a few wheat grains. Into this Hydra are introduced, and when the balance has been established, the crustacean food of the Hydra may be kept just slightly in excess of the demands of the Hydra inhabitants by the addition of some pabulum from time to time. Such Hydra can then be made use of, as explained before, to start the

intensive cultures, which, under ordinary circumstances, will be required only once a year.

In our aquaria containing Hydra, desmids tend to accumulate. Pond gatherings found to contain crustaceans (e.g. cyprids and cyclops) can conveniently be added to such Hydra-containing aquaria, since "catches" revealing much crustacean stock are not likely to prove useful for yielding Amœbæ. Hence a "catch" which has been a blank as regards protozoa may be utilised for this purpose. Green Hydra frequently turn up in pond gatherings. These subsist on a much less plentiful crustacean diet, and are easily grown in the laboratory. They are much more susceptible to change of *p*H than the brown. When setting up a sub-culture, do not add fresh water of any kind until the green Hydra are well established in the new environment, and even then add it sparingly when this is necessary to make up the bulk.

371. CULTURE OF HYDRA

J. T. Saunders

Hydra can usually be obtained by taking pond weed and placing it in a large bell-jar of water. After a day or two, the Hydra leave the weed and attach themselves to the walls of the vessel, in which they are easily seen. If these Hydra be transferred to a bowl of clean water and fed on Daphnia, they will multiply very rapidly indeed, and a large stock will be obtained. The process of catching the food is easily observed if the Hydra are starved for a few days and then presented with a few Daphnia. These are caught almost immediately by the tentacles and very soon taken into the enteron to be digested. In contrast with the starved forms, it will be observed that Hydra surfeited with food allows Daphnia to come into contact with its outspread tentacles without making any response.

372. CULTURE OF PARAMECIUM

Monica Taylor, S.N.D.

Old " gatherings " from ponds, macerated water weeds that have been stored in the laboratory for some time, serve for inoculation material, as well as freshly dredged mud from slow-flowing streams, etc. Take a small quantity of this débris, add fresh water to it, and supply with a pabulum consisting of wheat grains, beans, chopped leaves or bread. In a period of time, wholly depending on the temperature and the character of the pond gatherings used, but usually not longer than a fortnight, a crop of Paramecia will appear in the aquarium. I find it useful to centrifuge the animals, so as to be able to give to each student a liberal supply in a small drop of water. After Paramecia requirements are over for the time being, the pond gatherings may again be stored until another occasion. In setting aside this material, it is a good thing to add a store of pabulum to it, and to cover it over with a glass plate to prevent its drying up completely.

373. CULTURE OF SPIROSTOMUM

J. T. Saunders

Spirostomum ambiguum is a very large ciliate and rather a good subject for experiments. It suffers from the drawback that the micro-nucleus is very difficult to demonstrate, and it is not very easy to rear. However, its large size makes it desirable, for human nature is generally impressed by this, and very small objects are apt to be treated with contempt. Spirostomum occurs in Nature in ponds and stagnant ditches, but is very susceptible to environmental changes, as can easily be demonstrated experimentally.

Spirostomum is best reared in test-tubes which are not too small in diameter · about 1 in. diameter and 5–6 in.

in length is a good size. Fill each test-tube about two-thirds full with tap water, and place at the bottom of each a wheat grain or two. These wheat grains should be boiled, to prevent germination. The decay of the wheat grains provides food for the growth of Spirostomum. After three or four days, a few Spirostoma are placed in each test-tube, and the tubes are set aside. If a dozen tubes are started off in this way, several of them will produce flourishing cultures of Spirostomum. The growth of small flagellates in these tubes is often too vigorous to allow the Spirostoma to flourish, but they are a useful by-product and serve for several striking experiments. These flourishing cultures persist for a few weeks and then die out. They can be sometimes revived by the addition of another fresh grain of boiled wheat, but it is generally best to sub-culture.

The object of rearing the Spirostoma in test-tubes is to present a small surface for the diffusion of the carbon dioxide produced in the decay of the wheat grain. This carbon dioxide prevents the water from becoming too alkaline for the Spirostoma to live in, but at the same time we must not check the diffusion altogether, or the water becomes devoid of oxygen and deleterious substances are produced by anaerobic decomposition. If we hit the conditions off right, the Spirostoma flourish ; if, however, the culture fluid appears to be going white or milky, owing to the superabundant growth of small flagellates, we can sometimes check this by blowing air through the liquid in the test tube, once or twice a day, with an ordinary pipette.

EXPERIMENTAL ZOOLOGY

374. GENETICS

Julian Huxley

A little Amphipod, *Gammarus chevreuxi*, forms admirable material for simple genetical experiments. It can be obtained from Mrs. Sexton (The Laboratory, Citadel

Hill, Plymouth) and Mr. P. A. Tratman, of The Museum, Oxford. The animal lives in brackish water (4 parts tap water to 1 part sea water; probably a solution of Tidman's Sea Salts would be effective). It is omnivorous, but the most satisfactory diet is dead elm leaves (collect in autumn, keep dry, wash and then soak in the brackish water for a week or so before using) The addition of a little Ulva (probably some fresh-water plant could be substituted) is beneficial. The water needs changing only if scum forms.

Three pairs of Mendelian characters are known, all affecting the eye. The normal eye has black facets on a white ground. A mutant factor (b) is found which converts the black (b) facets to red; another (c) which prevents the formation of colour facets and leaves the eye white (albino) instead of coloured (C); and a third (w) which prevents the formation of white (W) between the facets.

Thus, the normal wild stock has the genetical formula BBCCWW. bbCC(c)WW(w) is red plus-white, bbCC(c)ww is red-no-white. Any animal with ccWW(w) is albino; and a combination of cc and ww produces a wholly colourless eye, without either facet-colour or white. In addition, B and C are linked. With this material, various exercises can be carried out.

(*a*) A mixed stock can be provided and the different constitutions of the various phenotypes determined. For instance, a "colourless" individual may be carrying BB, Bb or bb, and a red may be either bbCCWW, bbCcWW, bbCCWw, or bbCcWw. A cross between a red and a colourless, however, will reveal, by the composition of its F_1, the precise constitution of both its parents; and similarly for other phenotypes. The results of the whole class should be written up together. This is an admirable exercise for accustoming boys to the difference between phenotype and genotype.[1]

[1] Phenotype = characteristic type as determined by its visible appearance. Genotype = characteristic type as determined by its genetical constitution (Johannsen's terms).

(*b*) After such tests have been made, pure stocks, such as bbCCWW, BBccww, etc., can be built up by appropriate crosses and tests. This is also a good exercise as showing how Mendelism is applied in practice.

(*c*) Dominance in F_1, 3 : 1 and 9 : 3 : 3 : 1 F_2 ratios, 1 : 1 and 1 : 1 : 1 : 1 back-cross ratios can then be demonstrated. The demonstration of the identity of F_1 and F_2, whichever way the factors are brought in in a two-factor cross, is always impressive. For example, red-and-white (bbCCWW) × black-no-white (BBCCww) gives the same F_1 and F_2 as does the cross wild type (BBCCWW) × red-no-white (bbCCww).

(*d*) If desired, it is easy to demonstrate linkage. Stocks are made up for coupling $\frac{(BC)}{(bc)}$ or repulsion $\frac{(Bc)}{(bC)}$,[1] and mated to double recessives (bbcc). If there were no linkage, the blacks and reds should be in equal numbers; as a fact, the first cross gives an excess of blacks, the second a similar excess of reds. The linkage is much stronger in the male than in the female. Unfortunately, no sex-linked factor has yet been discovered.

(*e*) The gradual development of the male secondary characters, moult by moult, is an interesting study in the physiology of development. The sexes can easily be distinguished (but only at maturity) by the fact that the male bears many and curved hairs on the second antenna (and elsewhere), and by the shape and large size of the gnathopods: the female has few and straight hairs on the antenna, and the ovary is readily visible as a dark organ astride the front half of the gut. The rapidity of reproduction is, of course, a function of temperature. 20° C., or a little over, is the most convenient temperature. At this the broods succeed each other about every twelve days for several months. The young hatch in the brood pouch and are extruded at the mother's next moult.

[1] The factors in association on either side of the line denote those in the same chromosome. In the first case ("coupling"), the stock is made by crossing wild type with double recessive albino; in the second, ("repulsion") by crossing albino carrying black with homozygous red.

They are best examined by pipetting several out on to a slide or glass plate and examining, after draining the water off, with a ⅔-in. lens. If desired, they can be narcotised in the vapour of a mixture of ether and chloroform, but this is not necessary for eye-colour determinations.

From time to time the pairs should be transferred to new dishes with most of their water, leaving behind the mass of fæces which makes the detection of the young difficult. The best vessels for keeping the animals are used tongue-jars, to be obtained for a few pence each from rag-and-bone merchants. They should be covered with glass plates.

375. ENDOCRINE GLANDS

Julian Huxley

(*a*) The effect of thyroid on the metamorphosis of frogs is very simply demonstrated. Take half-grown tadpoles with small or medium-sized limbs. Starve for a couple of days, and feed on fresh thyroid obtained from the butcher; or, squeeze fresh thyroid juice into their container; or, add powdered desiccated thyroid, as obtained from any chemist. One or two meals of the gland, or twenty-four hours' immersion in a solution, is ample. Keep some untreated animals as controls. Note after a few days, progressive emaciation, growth of limbs and absorption of tail in the treated animals. Most die during forced metamorphosis, but the mortality, if desired, can be kept down by placing them in an atmosphere of oxygen.

Iodine will also accelerate metamorphosis, but much less notably. Make a saturated solution of iodine crystals in tap water. Determine the lethal concentration for tadpoles. Make up three vessels containing tadpoles with water, weak iodine, and strong (but sublethal) solutions respectively. Renew the solutions twice weekly.

There should be a graded series as regards metamorphosis. If quantitative data are desired, kill the tadpoles after two to four weeks, and measure body length, tail length and hind-limb length. Those in the strongest iodine solutions should have the largest limbs and shortest tails. This illustrates the rôle of iodine in the formation of thyroid secretion.

The temperature coefficient of thyroid- (and iodine-) induced metamorphosis can also easily be found. Immersion in substances such as alcohol (½–1 per cent.) decreases the rate of artificial metamorphosis, although metamorphosis will take place in solutions of urethane strong enough to produce complete narcosis.

(*b*) The pigmentary effect of pituitary (posterior lobe) is also easily studied. The most instructive method is to obtain a whole pituitary body (ox) from a slaughter-house, show the class the two lobes, and make an extract of the posterior lobe in normal saline solution. Commercial extract can also be used, if desired. Have a series of pithed frogs, which have previously been made pale by keeping in a white dry dish. Inject ½–1 c.c. of various dilutions of the extract into the dorsal lymph-sac (or peritoneal cavity). In about an hour they will turn a deep black.

Quantitative study may be made by observing the greatest dilution which will cause darkening. (The weight of fresh posterior lobe per unit of body-weight of frog which will just cause darkening is a constant.) After a further period, the dark colour disappears. This experiment was suggested to me by Dr. L. T. Hogben of Edinburgh, and acts admirably in practice.

These two experiments illustrate (*a*) the morphogenetic and (*b*) the transitory effects of endocrine organs respectively, and are the only ones of the kind, so far as I am aware, which can be performed without any special precautions or apparatus.

376. REGENERATION

Julian Huxley

Hydra of all species, Planarians, and fresh-water Oligochætes (especially Lumbriculus) all illustrate regeneration simply and well. Planarians are perhaps the best material. Catch in ditches and ponds. They will assemble in the folds of crumpled paper thrown in some days previously, or in bottles in which pieces of boiled earthworm have been placed. (Leave the bottles a few hours before hauling in.) The common brown Planaria and the black Polycelis are hardier than the white Dendrocœlum (which, however, is not unsatisfactory).

Place on damp blotting-paper, and cut with a sharp scalpel when extended. Transverse, oblique and longitudinal cuts should be made. The share of restitution (by new growth) and morphallaxis (rearrangement of the old tissues) in regeneration can be beautifully studied, as also the direction of the new growth in relation to the cut surface. By cutting a number of small pieces of the same size from the same region of the body of a number of worms, the effects of various agencies on regeneration can be tested. For instance, 1 per cent. alcohol, or temperature close to freezing, greatly reduces head-frequency (i.e. the percentage of cases in which a head is regenerated).

This last experiment can be combined with another to demonstrate in a very striking way the influence of one part on the development of others. For this the pieces must be cut from the region immediately behind the pharynx. Make up a series of vessels each with a number of pieces in tap water, ½ and 1 per cent. alcohol respectively.

(*a*) Determine the head-frequency in the various solutions after three to five weeks.

(*b*) It will be found that all pieces with regenerated heads will have formed a pharynx in the old tissue, while

none of those without heads will have been capable of this.[1]

(To see the pharynx, examine under a cover-slip, gradually draining the water away so as to exert pressure on the animal.) No food need be provided in these experiments.

377. REDUCTION

Julian Huxley

If intact Planarians are left in tap water without food and measured, say, once a month, they will be found to decrease in size, since they have the capacity of living on their own tissues. Find out how far this process can go. (It can go to very surprising lengths !) If desired, the process can be reversed by feeding, e.g. on small bits of boiled earthworm. By means of alternate starving and feeding, the animals can be kept from ageing,[2] since size-decrease, due to starvation, is accompanied by rejuvenescence.

378. GRAFTING

Julian Huxley

Segments of large hydra can be spitted on fine glass rods, or on hairs, which are then stuck into dishes lined with paraffin. By this means, pieces can be made to unite. Various combinations with regard to polarity can be studied. According to Crampton, moth pupæ can readily be grafted. They are cut with a sharp razor, the cut surfaces brought together, and the wound-line cemented with low-melting paraffin wax. Each part produces what it would have produced in the intact organism ; thus, very strange combinations can be realised at emergence.

[1] Child, *Individuality in Organisms*. Chicago, 1915.
[2] Child, *Senescence and Rejuvenescence*. Chicago, 1915.

379. DEDIFFERENTIATION AND RESORPTION

Julian Huxley

Obtain Obelia and Campanularia from a marine laboratory. Cut off small branches with 1–10 hydranths, keep in small capsules of sea water (not renewed), and examine if possible every morning and evening. In one to three days it will be found that the mouth closes, the tentacles are reduced, become mere knobs and disappear; the hypostome disappears, the whole hydranth shrinks, owing to the migration of cells into the cœlenteron, and is finally reduced to a tiny knob. If desired, the process can be accelerated by adding *extremely* small quantities of poison, e.g. immersion in $HgCl_2$ $\frac{N}{2{,}000{,}000}$. If single hydranths are cut off just below the hydrotheca, they will also dedifferentiate, but cannot be resorbed. Their final stage is therefore an ovoid sac filled with cells.[1]

380. DISSOCIATION AND RECONSTITUTION

Julian Huxley

A very striking experiment can quite easily be performed with sponges. Obtain Sycon or Grantia from a marine laboratory. Cut into pieces with scissors. Take up a number of pieces and squeeze between the fingers above a flat-bottomed vessel of sea water until this shows a *faint* milky appearance. This is due to the cells of the sponge, which are broken from their attachments and squeezed out in small groups or singly. They settle as a film. This changes gradually (by amœboid movements of the cells) into a series of irregular masses, which become gradually sharper and more spherical. Pipette these up (after about one day) and transfer to fresh sea water. Change the water every one or two days (not much water is required). If the culture stays clean and healthy, various stages in the regeneration of the

[1] Huxley and de Beer, *Q.J.M.S.*, 1923.

spheres can be followed—the migration of the dermal cells to form an outer layer, the production of spicules, and the hollowing out of the originally solid central mass of collar cells to form a gastric cavity. This is perhaps the most striking example of regeneration and reorganisation known.[1] It is stated that the same experiment can be performed with fresh-water sponges. If these are available, it should simplify matters.

381. BIOMETRIC METHODS

Julian Huxley

When at the sea-side, collect several hundred shore-crabs (*Carcinus mœnas*); if possible, all the discoverable specimens of all sizes in a given area. Preserve in alcohol. With a pair of compasses or callipers make a record of the following measurements on such specimens:

1. Greatest breadth of the carapace.
2. Breadth of abdomen (at the penultimate joint).

Record also the sex of each individual. Calculate the percentage ratio of abdomen breadth to carapace breadth

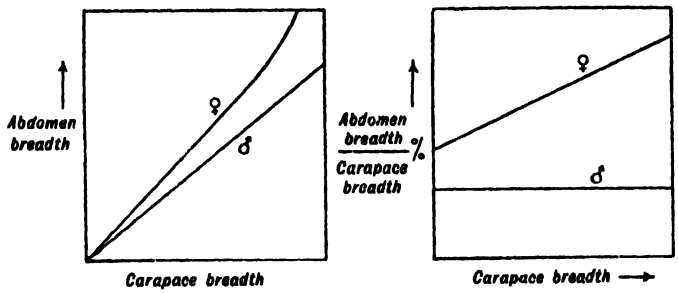


Fig. 238.

for each specimen. Group the material (1) by sex, (2) within either sex, into classes of differing carapace width. Find the average abdomen breadth for each class, also the average $\frac{\text{abdomen}}{\text{carapace}}$ percentage ratio. Plot

[1] Huxley, *Phil. Trans.*, 1911.

curves for both these variables against carapace breadth. It will be found that the types of results shown in Fig. 238 will be obtained.

The measurement and statistical treatment have shown:

(1) That the male abdomen remains of the same relative proportions throughout life, growing at the same rate as the carapace.

(2) That the female abdomen, on the other hand increases in relative size throughout life, growing throughout at a rate faster than the carapace.

(3) The superiority of one method over the other. (The second method of treating the same data brings out small differences of proportion much more clearly.)

(4) That there is no sudden change in the growth rate of the female abdomen such as one might have expected at the onset of sexual maturity.

If all the crabs are from the same locality, and the selection has been indiscriminate, we may also construct another curve, namely, for the numbers in each size-class. This will probably show several peaks or maxima, each peak corresponding to the mean of one year's crab population. If so, mere analysis and observation will have enabled us to determine the average annual growth of crabs without direct experiment. Crabs are particularly good material, because they are easy to obtain and have easily measured bodies and organs. However, no doubt suitable land or fresh-water material could be found.

FUNGI GROWTH

382. SPORE GERMINATION OF FUNGI

Eric Ashby

A number of slides are washed in methylated spirit, dried in a flame and laid on blotting-paper soaked in sterile water, in a large Petri dish. A tube of malt agar is heated and a few drops are poured on to each slide. When the agar has set, inoculations are made from a suspension of *Rhizopus* spores in sterile water. The

slides are left for a few hours in the incubator at 25° C., or in a warm place, and then examined under the microscope. The spores will be seen in the early stages of germination, and the rate of growth may easily be measured with an eye-piece micrometer. The suspension of spores should not be too dense, or it will be impossible to distinguish the individual germ tubes from one another.

383. MODE OF GROWTH OF FUNGI

Eric Ashby

Plate cultures of *Rhizopus nigricans*, *Fusarium*, *Botrytis cinerea* and *Aspergillus* are set up, and kept in the warm cupboard. After a fortnight or three weeks, the different types of growth and the different reproductive bodies will be very strikingly exhibited. In the Fusarium cultures, a falling off of growth will take place, owing to the "staling" action of the fungus. This staling is probably due to the formation of a bicarbonate by the carbon dioxide of respiration.[1]

384. THE EFFECT OF TEMPERATURE ON GROWTH

Eric Ashby

Ten or more plates of malt agar are poured and inoculated with a spore suspension of Fusarium. The inoculations should be made in the middle of the plate and must be about the same size. Half the plates can then be put into the incubator, or warm cupboard, and half in a cool place whose temperature is fairly constant. The temperatures are recorded, and the diameters of the colonies measured with a ruler every day. The averages of the two sets of plates will give a good idea of the effect of temperatures on fungal growth.

The experiment may be repeated, with a view to illustrating the differences in growth under light and

[1] Pratt, C. A., *Anns. Bot.*, 38, 1924.

darkness; but the plates in the dark, and those in the light, must be at exactly the same temperature.

385. HUMIDITY AND GROWTH

Eric Ashby

Humidity is one of the determining factors in fungal infection; and the following experiment is designed to illustrate the influence of humidity on the normal growth of the fungus.

Nine plate cultures of *Botrytis cinerea* are set up. It will be necessary to use small plates for the cultures. When growth has begun, the cultures are exposed in three glass dishes, three in each dish; the dishes containing 10, 30 and 50 per cent. sulphuric acid, respectively. The best way to do this is to stick the culture dishes to

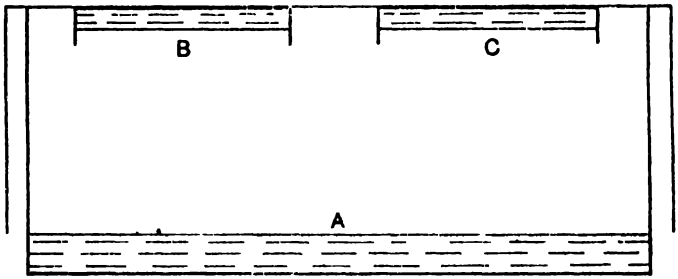


FIG. 239.—Humidity experiment: A, dish with sulphuric acid; B and C, inverted plates fixed to the lid; cultures facing downwards.

the inside of the lid of the big dish, with the colonies facing downwards (Fig. 239).

386. THE ELEMENTS ESSENTIAL FOR GROWTH

Eric Ashby

For this experiment five sets of medium are necessary. The first has the composition:

Glucose	2	grams
Asparagin	2	
K_2PO_4	1·25	
$MgSO_4$	0·75	
Agar	15	
Water	1	litre

Each of the other four is lacking in one of the nutrient constituents. Plates of these media are prepared, and inoculated with a culture of Fusarium. The effect on growth of the absence of the various constituents can be seen in about ten days. The most striking differences are to be observed in the spores, which in some cultures are vacuolate, and in others granulate. It will be found, too, that all the cultures become alkaline in reaction, except those to which no asparagin has been added.

This type of experiment can be varied indefinitely if time allows. Growth at various acidities, with various concentrations of the medium, and with various sources of the essential elements, may be studied in the same way.

HISTOLOGICAL METHODS[1]

387. FIXING

D. M. Reid

Before any piece of tissue can be prepared for microscopic examination, it must be killed as suddenly as possible and fixed in that state. There are certain fluids which will perform this function in a remarkably simple manner without necessitating great skill or knowledge on the part of the operator.

The most generally useful are :

(1) Chromo-acetic fixative (Fleming's formula) :

Chromic acid	. .	0·25 per cent. in water
Glacial acetic acid	.	0·1 ,, ,, ,,

This solution may be used for fixing any tissue and is specially valuable for fixing dividing nuclei. Pieces of tissue to be fixed should be as small as possible.

The material is fixed by dropping it into the solution and leaving it for twelve to twenty-four hours. On removing the tissue from the fixative, it must be washed

[1] The methods selected in the following notes are considered adequate to the standard of practical work in the biological laboratories of schools.

in water and then graded up through 30, 50, 70 and 90 per cent. strengths of alcohol.

(2) Formal-alcohol:

10 per cent. formalin	.	.	50 parts.
70 „ „ alcohol	.	.	50 „

This is a very good fixative for plant histology. It has the advantage of acting as a preservative as well as a fixative. Therefore it is invaluable for work in the field. I believe it has been used with some success for animal histology, but further than that I have found it very successful for the fixation of chick embryos. I have no knowledge of its general efficacy.

(3) Corrosive sublimate, in the form of a hot or cold saturated solution, makes a very powerful killing and fixing agent for worms and similar animals. The drawback of sublimate, however, lies in its habit of crystallising out after the specimen has been mounted on a slide. This can be overcome by washing out the sublimate from the specimen with numerous changes of 70 per cent. alcohol to which a little iodine has been added—so long as there is corrosive sublimate present, it takes the colour out of the iodine.

At one time there were certain fluids recommended which stain the tissue as well as fix it. This method is not at all satisfactory, since it does not allow of critical work.

For such material as chick embryos, Kleinenberg's picro-sulphuric fixative is very good. However, it has two drawbacks: (*a*) it stains the embryo yellow; (*b*) it has a tendency to make the specimen very brittle. Indeed, I have found formal-alcohol serve as well as, if not better than, Kleinenberg's for this type of work.

Kleinenberg's fixative:

Picric acid, saturated solution, 20 c.c.
Distilled water, 400 c.c.
Sulphuric acid, 2 c.c.

Tissues are immersed in this fluid for about four to

twelve hours, depending on the size; they are then washed in 70 per cent. alcohol and are preserved finally in 90 per cent. alcohol.

388. EMBEDDING

D. M. Reid

When material has been properly fixed, it should be graded up through the various strengths of alcohol to 90 per cent., in which it should be kept until ready for embedding. Of course, the best plan is to embed the tissue and preserve it in that state. The principle underlying embedding is the infiltrating of the tissue with some material which will set quite firm and offer an even resistance to the cutting knife.

The two most commonly used embedding substances are paraffin wax and celloidin. The former is used with most success with fairly soft material, such as leaves, muscles, glands and similar tissues, and these tissues are cut best on the "rocker" type of microtome. On the other hand, celloidin is the best embedding material for hard tissues, such as plant seeds, stems, developing bone, etc. For this the "rocker" microtome is useless, and the best mechanical microtome is the "sledge." However, I have found the common hand microtome which can be clamped to the table to be, after a little practice, a very efficient instrument.

When infiltrating a piece of tissue, great care must be taken that every particle of water is removed, or distortion of the structure will occur. Therefore the tissue must be washed in two or three changes of absolute alcohol. Now let us suppose we are going to treat a piece of liver. The following would be the method of procedure:

(*a*) Dehydrate in absolute alcohol.

(*b*) Transfer to a mixture of one-quarter cedar oil plus three-quarters absolute alcohol for twenty-four hours.

(*c*) Transfer to a mixture of one-half cedar oil and one-half absolute alcohol for same period.

(*d*) Transfer to a mixture of three-quarters cedar oil and one-quarter absolute alcohol for same period.

(*e*) Transfer to pure cedar oil until clear.

Now the liver is taken from the oil and dropped into a test-tube of soft wax (melting point about 30° C.), which is kept just above the melting point. It is allowed to remain in the wax for about six hours, when it is taken out and placed in a paper cell (the greased tray of a matchbox is convenient), and melted hard wax (melting point 50° C.) is poured over it.

On cooling, a block of wax containing the specimen should be cut out, labelled, and put away in a dry place for future use.

The celloidin method does not involve the heating of the specimen, and so may score in certain places over the wax method. The procedure is as follows:

(*a*) Grade up the tissue through the alcohols to absolute alcohol.

(*b*) Wash in a few changes of absolute alcohol.

(*c*) Transfer the tissue to a mixture of equal parts absolute alcohol and ether.

(*d*) Add a few chips of celloidin, and as they are dissolved, add a few more, and so on, until a thick, syrupy mass is formed.

(*e*) Remove specimen with a section lifter to a bottle of chloroform, to cause the celloidin to set.

(*f*) Preserve in 90 per cent. alcohol.

Of course, when removing the specimen from the celloidin to the chloroform, it is necessary to lift it so that it retains a thick envelope of celloidin. The foregoing method I have found to be more successful than the method of having a thin and a thick solution of celloidin, since it is not necessary to expose the specimen to the moisture of the atmosphere when transferring it from one solution to another

389. SECTION CUTTING AND MOUNTING

D. M. Reid

(A) *Paraffin.*—If the piece of tissue is embedded in paraffin, it should be cut on a rocker microtome, by which a long ribbon of sections is procured, thus facilitating manipulation. This ribbon is then cut into convenient lengths and laid on the surface of some warm water in such a flat dish as a saucer. If the water is at the right temperature, the sections will become perfectly flat. Now a slide smeared with a very small amount of egg albumen is dipped into the water and the ribbon is drawn on to it with a brush. If only one section is required on the slide, the others are cut off and pushed back into the water. The finger is now *rolled* over the section to squeeze off the surplus water and, incidentally, to make the section lie flat. The slide with the specimen can then be put into an oven for twenty-four hours to allow the egg albumen to coagulate. On removal from the oven, the slide should be passed through a Bunsen flame a few times until the wax surrounding the specimen is melted ; then drop the slide into a pot of xylol to dissolve the wax. Next :

(*a*) Pass the slide through 90 per cent alcohol to

(*b*) Water, and stain in some aqueous stain, e.g. Delafield's hæmatoxylin.

(*c*) Now place slide in 90 per cent. alcohol and

(*d*) Stain in a counter-stain, e.g. eosin.

(*e*) Wash in 90 per cent. alcohol, and having

(*f*) Dehydrated in absolute alcohol,

(*g*) Clear the section in xylol and

(*h*) Mount in Canada balsam.

Pots made to hold about ten pairs of slides can be bought from some of the dealers. These pots are very convenient, since it is not necessary to touch the slides, the various fluids being poured from one pot to another.

(B) *Celloidin.*—With regard to celloidin sections, the process of staining and mounting is very different. As

each section is cut, it is dropped into 90 per cent. alcohol. Now these sections must not be put into any strength of alcohol other than 90 per cent., so the stains used must be in alcoholic solution. The staining, etc., is carried out in this manner:

(*a*) The sections are in a pot of 90 per cent. alcohol.

(*b*) Pour off the alcohol and stain with, say, Kleinenberg's hæmatoxylin.

(*c*) Wash in 90 per cent. alcohol and

(*d*) Counter-stain in eosin.

Now it will be found that the celloidin has taken up the stain, so wash the sections in a weak solution of HCl in alcohol. This acid solution will remove the stain from the celloidin without affecting the specimen. Really, the best plan is to overstain slightly in order to be quite safe. The amount of overstaining necessary can be found only by practice. When the excess stain has been removed, wash the section in a few changes of alcohol and clear in terpineol. Clove oil, xylol, etc., cannot be used. When clear, pour the terpineol off and replace it with a thin solution of benzole balsam. The sections can be kept in this medium for years Mount in thicker balsam.

390. STAINING

D. M. Reid

The staining of a tissue involves more than a mere addition of colouring materials to that tissue, for the real purpose of staining is to define clearly the various structures of which the tissue is built up. The selection of a stain depends on four primary things, viz.:

(1) The type of tissue.

(2) Structures to be demonstrated.

(3) Character of the fixing fluid; and

(4) The embedding material.

(1) By type of tissue, animal or vegetable is intended, and although such stains as Delafield's hæmatoxylin and eosin form an admirable combination for both types,

many stains of great service botanically are of little use for animal work, and vice versa.

(2) Certain structures take up stains more rapidly than others. A common example of this is found in the cell and its nucleus, even when only one stain has been used.

(3) A knowledge of the fluid used for fixing the tissue is essential, since many fixing agents prevent the entrance of certain of the less "penetrating" stains. Other fixing agents, such as corrosive sublimate, are partial to the latter type of stain.

(4) Remark has already been made as to the use of no other than alcoholic stains with celloidinised material. With material in paraffin wax, however, either kind of stain may be used.

(5) One point to remember is never to stain a piece of tissue before embedding; it is, at best, a rough-and-ready method allowing of no accurate work.

Stains may be divided conveniently into three classes, viz.:

(1) Plasmic stains, such as are used for staining cell walls and contents, i.e. a general protoplasm stain. The plasmic stains of most general applications are eosin and erythrosin (1 per cent. solution in 90 per cent. alcohol). They are the usual counter-stains for all general work, and are used as already directed.

(2) Nuclear stains, which stain the nuclei only; for example, Delafield's hæmatoxylin:

Saturated solution in H_2O of ammonium alum, 400 c.c. 16 per cent. solution of hæmatoxylin in absolute alcohol, 25 c c.

Leave this to ripen in an unstoppered bottle in daylight for four or five days, and then add:

Glycerine, 100 c.c.
Methyl alcohol, 100 c.c.

Allow mixture to stand until it is of a deep bluish colour, filter and keep in a stoppered bottle. This is an aqueous stain.

Methyl blue, another aqueous stain used like the former:

Methyl blue, 0·25 gram.
90 per cent. alcohol, 20 c.c
Distilled water, 80 c.c.

(3) For cytological work, the best stain I know, giving the clearest definition, is Heidenhain's hæmatoxylin, of which there are two solutions:

(*a*) The mordant and
(*b*) The stain.
 (*a*) Potassium chlorate, 1 gram.
 Distilled water, 300 c.c.
 (*b*) Hæmatoxylin, 1 gram.
 Distilled water, 300 c.c.

The section should be fixed on the slide as formerly, and when the paraffin has been removed and the section washed in water, it should be placed for about twenty-four hours in solution (*b*), then transferred for a similar time to solution (*a*). When that has been done, the slides should be rinsed with water, dehydrated, cleared in xylol and mounted in Canada balsam. It will be found that the cells have stained a light blue and the nuclei a darker blue, while any mitotic figures which are present will be a dark blue, almost black.

391. STAINS FOR CHROMATIN IN FRESH MATERIAL

Cambridge, 1923

For rapid staining of fresh material, Cotton Red (Gossypimene) + Picric Aniline Blue, and Iron Acetocarmine are very useful. The formula for the former is as follows:

(1) Gossypimene, 2 grams.
 Distilled water, 900 c.c.
 92 per cent. alcohol, 60 c.c.
 Time, about 15 minutes.

(2) Aniline blue, 2 grams.
Picric acid, 1 gram.
80 per cent. alcohol, 1,000 c.c.
Time variable, but can be determined with a little practice.

The Iron Acetocarmine method for chromatin consists in placing the fresh material to be examined direct in a drop of acetocarmine on the slide. The iron is added merely by stirring the material in the drop with a pair of ordinary teasing needles before putting on the cover-slip. In one minute the nuclei are satisfactorily stained.

METABOLISM

392. VALUE OF GREEN, BLUE AND RED LIGHT

E. J. Moore

For this experiment it is necessary to prepare a simple screen as follows. Take a glass cover for making lantern slides and paste on it a ½-in. margin of black paper; take ½-in. strips of Kodak Tri-colour Filter (gelatine), green, blue and red, and paste these across the slide, side by side, so leaving a strip of "white" light at the end. Cover with another piece of glass and bind together like an ordinary lantern slide.

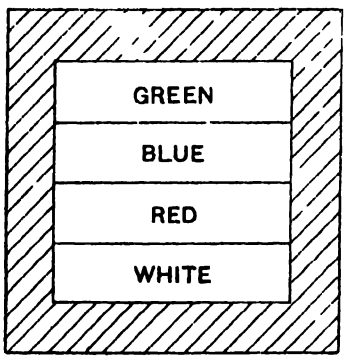


FIG. 240.

For the experiment, a large destarched leaf, e.g. Primrose, is taken and laid on a wooden block with its stalk dipping into water. Lay the slide on the leaf and make a careful sketch of the position of leaf and screen. Place the apparatus in a well-lighted position for several hours and test for starch, noting the

relative amounts under the white, red, blue and green portions and under the black margin.

393. ABSENCE OF STARCH FROM MONOCOTYLEDONOUS LEAVES

E. J. Moore

Expose leaves of Onion or Snowdrop to the light for several hours and then test for starch. The absence of starch in many Monocotyledons is an important discovery.

394. CONVERSION OF STARCH INTO SUGAR

E. J. Moore

Take a little starch paste, made by mixing 1 gram of starch with 5 c.c. of water and boiling for 1 min. in 250 c.c. of water, and test with iodine solution. Take a small amount of similar paste, add to it a small amount of hydrochloric acid, and boil the solution for a short time. Now test with iodine solution

Take a small amount of starch paste and add to it an equal volume of diastase solution, leave in a *warm* place and test for starch, after periods of half an hour.

Turn over in the mouth, for several minutes, some dry starch; possibly the change to a sweetish taste will be noticed.

These experiments should lead up to a discussion of the relation between starch and sugar, often readily seen when the empirical formulæ are known.

395. FORMATION OF STARCH FROM SUGAR IN DARKNESS

E. J. Moore

Take several healthy destarched leaves of Enchanter's Nightshade (or other available plant), and place them in

a 10–15 per cent. sucrose solution *in a dark cupboard* and leave for twenty-four hours. Remove leaves and test for starch.

The formation of starch in the dark ought to suggest the possibility of light being necessary, not for starch formation, but for the formation of a substance from which the starch is formed. This experiment may suggest a sugar as that intermediate product, and from this a theoretical consideration of the chemistry of carbon assimilation should develop.

396. CHLOROPHYLL IN THE RED ALGÆ

E. J. Moore

The Red Algæ (*Rhodophyceæ*) are frequently red or purple in colour, owing to the presence of a pigment, phycœrythrin, the nature of which is not yet fully established, and which is not, apparently, a carotinoid pigment. The presence of chlorophyll and phycœrythrin may be demonstrated as follows :

Two lots of fresh material of the alga *Rhodymenia* (obtainable from most Biological Stations) are taken.

One portion is boiled for 15 mins. in water, and is rinsed with 96 per cent. alcohol. It is now packed into a suitable stoppered bottle, covered with alcohol, and left for a week in a dark cupboard. After this time, if the liquid is poured off, it will be a bright green solution of crude chlorophyll.

The second portion is washed in tepid water for 1 hour. It is then cut into small pieces, packed into a tall cylinder and covered with distilled water (one or two drops of mustard oil should be added to prevent bacterial activity). The cylinder is left for about a week in a warm place. If the water is now poured off, it will be found to have a rose-pink colour, and to display an orange fluorescence, due to phycœrythrin.

397. CHLOROPHYLL IN THE BROWN ALGÆ

E. J. Moore

The Brown Algæ (*Phæophyceæ*) are characterised by the presence of an extra carotinoid pigment, fucoxanthin, which masks the chlorophyll present.

If a fresh *Fucus* thallus is dipped into boiling tap water, it assumes a vivid green colour. This, however, disappears as the thallus cools again.

A green extract of crude chlorophyll can be readily prepared from a fresh *Fucus* thallus, by mashing the thallus in a mortar with 96 per cent. alcohol. The resulting extract is not so pure green as that prepared from a green leaf, but it shows the same fluorescence, and its spectrum is very similar.

398. THE COMPONENT PIGMENTS OF CRUDE CHLOROPHYLL

E. J. Moore

The technique of chlorophyll extraction and the separation of its components are too tedious and complicated for an ordinary class-room demonstration.

A simple method of demonstrating the presence of the four pigments of the chloroplast may be carried out as follows:

A strong crude extract of powdered dry Nettle (*urtica*) leaves is made in 96 per cent. alcohol. A piece of *thick* white blotting-paper (filter paper is usually unsatisfactory) is placed over the mouth of a large beaker, and the chlorophyll extract is deposited in the centre, drop by drop, with a small pipette. As the extract spreads and dries off, a zoning of colour will be found at the limit of drying, and four distinct colours can be made out: to the outside will be found two yellow bands, and to the inside two green bands, indicating the carotinoids and chlorophylls respectively.

A variation in the method can be made by placing the

crude extract in a porcelain basin, and suspending a strip of blotting-paper, 1 in. wide, above it, with its lower edge just dipping into the extract. In this case the zones of colour will be found at the upper part of the strip.

399. TO MEASURE THE EFFECT OF MONOCHROMATIC LIGHT ON THE RATE OF PHOTOSYNTHESIS

Birmingham

The apparatus consists of a glass vessel, A, containing a shoot of *Elodea*, illuminated by a 500-watt lamp in a box, B, having a window, C, into which various coloured glass screens can be fitted. Both the lamp and the vessel containing the shoot are placed in glass baths, through

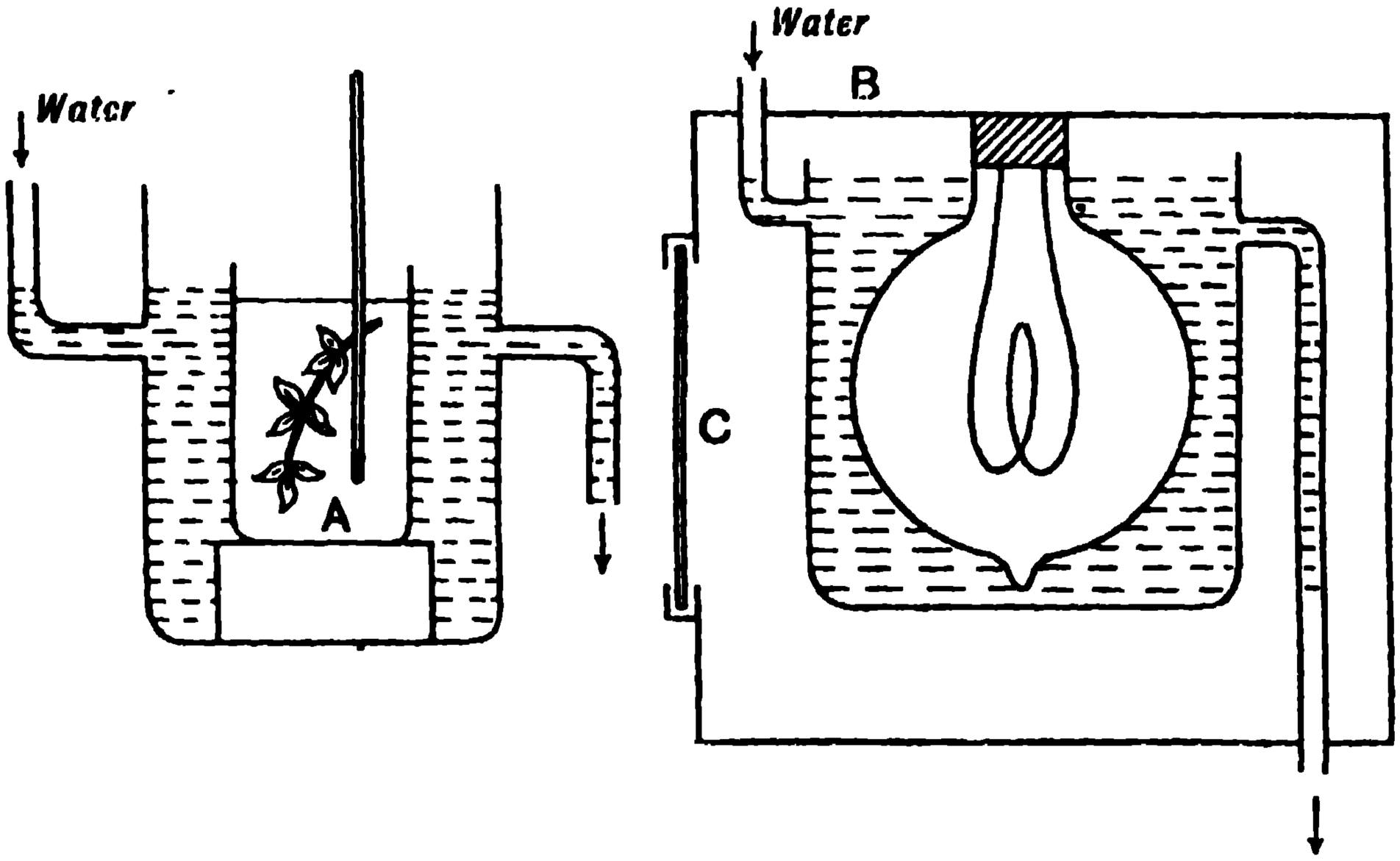


Fig. 241.

which water circulates to prevent heating and to maintain a constant temperature. The rate of photosynthesis is measured by the number of bubbles of gas evolved by the plant in a given time. There are two opposite illuminating chambers working on a double switch, so that, by alternate illumination, the one-sided effect is eliminated to some extent.

400. THE PRESENCE OF STARCH IN A SOLARISED LEAF

O. H. Latter

This is a modification of the usual experiment. The leaf is exposed to sunlight for some hours, gathered, placed in boiling water for a few moments, the chlorophyll removed by alcohol, and the alcohol washed out by water, after which the leaf is placed in iodine solution. So far the method is that usually adopted.

The leaf is now removed from the iodine, and at once placed in *benzole*. The benzole dissolves out the iodine from the cellulose walls of the cells and from the protoplasmic contents, but does not break up the blue starch-iodine compound. Hence the blue colour shows up very plainly in the leaf, being no longer masked by the yellow-browns of the iodine-stained cellulose and protoplasm. The usual method of showing the leaf when in the iodine solution makes a considerable demand on the imagination, for the colour produced by the starch-iodine is a dull purple-brown, i.e. a mixture of the colour produced in the starch with that in the other constituents of the leaf.

MICROSCOPY

401. THE MOUNTING OF SEEDS, ETC., FOR MICROSCOPIC EXAMINATION

A. Powell Jones

When permanent mounts of seeds are made, the seeds are commonly enclosed within a cell attached to a glass slide. Unless the cell and slide are very firmly joined together, they very soon part company when handled by students, and it was to overcome this failing that the kind of slide about to be described was experimented with. Strips of four-ply wood, consisting, in this particular instance, of two inner layers of birch sandwiched between two outer layers of mahogany, are cut into

pieces, 3 × 1⅜ in., and two circular holes are bored in each piece. Their diameter of ⅞ in. just permits an ordinary glass slide, 3 × 1 in., to cover them when laid lengthwise along the piece of wood. A slide is now glued on to the wood, by means of Croid glue, or some other easily handled and strong adhesive, and forms a basal wall to the two compartments. When the glue has

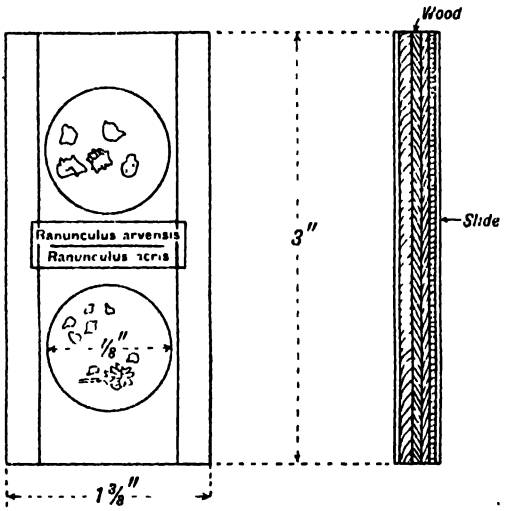


Fig. 212.

dried, seeds are placed in the compartments and can be fixed on to the slide or left free. Their names are printed in Indian ink, preferably, either on the wood between the compartments, or on a strip of paper that just fits over this area of wood. The strip of paper is now placed in position over a thin layer of adhesive, and is covered by a glass slide, which is glued on to the wood in the same way that the first slide was glued on, care being taken not to get any adhesive on the upper surface of the paper strip.

In this way permanent and labelled amounts of seeds are obtained; and experience has shown that after use, in class-work, for two years, none of the slides so prepared has been damaged in any respect.

If only small-sized seeds are to be mounted, three-ply wood could be employed instead of four-ply, to give shallower compartments; and although this type of slide has not been made and tested, there seems to be no reason why it should not prove serviceable.

The glass slides used were of 1-mm. thickness and proved satisfactory. They stood any strains that may have been put upon them during handling and any warping of the wood that may have occurred. Several were broken, however, when a solid piece of wood was used instead of ply-wood, for considerable warping then took place.

402. A SIMPLE STAGE MICROMETER

G. N. Ridley

The article to be described is suitable for laboratory class use since it can be made easily in any numbers, gives a satisfactory degree of accuracy and costs nothing. The usual price of a stage micrometer is 7*s.* 6*d.* This method was devised originally for determining stomatal density, but it can be used for measuring roughly the dimensions of cells.

A square of cigarette tin foil, the size of a cover-slip, is pierced with about thirty holes with a very fine sewing needle. This is done while the foil is held tightly across a gap between the edges of two thin micro-slides placed on a sheet of glass. This ensures that the needle shall penetrate the foil to a fixed distance, i.e. the thickness of one slide, thus producing a uniform series of *small* perforations. The diameters (which are remarkably constant) are then measured with a vernier microscope, and from the average of them the area of each pore is arrived at. A number of pores of area ·046 sq mm. and less can be produced.

To make the stomatal count, the foil is placed directly on the leaf epidermis, mounted in 10 per cent. glycerine and covered with a slip. The number of stomata visible

per circle is counted, the average obtained and the number per sq. mm. calculated.

Foils prepared under fixed conditions do not require individual standardisation. They should be kept under a label bearing the perforation area of the corresponding constant.

PLANT GROWTH

403. THE RATE OF GROWTH OF PLANT STEMS

W. B. Barker

Records obtained by the use of auxanometers offer not only an interesting and graphic method of studying variation in plant growth rate under varying conditions of temperature and light intensity, but also afford opportunity for *quantitative* determinations in plant physiology.

Descriptions of auxanometers are given in Strasburger's *Text Book of Botany*, Fritsch and Salisbury's *Introduction to the Study of Plants* and elsewhere. Messrs. Flatters & Garnett, of Manchester, supply an instrument which is illustrated in the second of the above books. This has the advantage of giving a permanent record on a smoked-glass plate, with hourly time markings.

The main features of the apparatus can be seen from the accompanying diagram. The necessary magnification is obtained by a lever. A writing point is attached to the end of the lever and bent so that it can be made to press on the recording surface. For the latter, stiff, well-glazed paper can be substituted. This is stretched and fastened to a three-ply board by drawing-pins and then smoked by means of a smoky oil flame, care being taken not to scorch or warp the paper by overheating. The lower edge of the frame, carrying board or glass plate, is fastened to an arm that is pivoted to the side of an upright, fixed to the base of the apparatus. The lower end of this arm carries a projecting piece, whose end is bent downwards at right angles. The clock has the

glass removed and is placed face upwards, so that the minute hand engages the bent projection sufficiently long to move the recording surface a short distance. As the hand passes on in its circular movement, the arm is disengaged, and the recording surface recoils to its former position. The automatic recovery of position is ensured by the frame carrying board (or smoked plate) being attached slightly to one side of the top of the arm. The lateral movement of the arm is restricted by two adjustable screws (not shown in the diagram). In this way

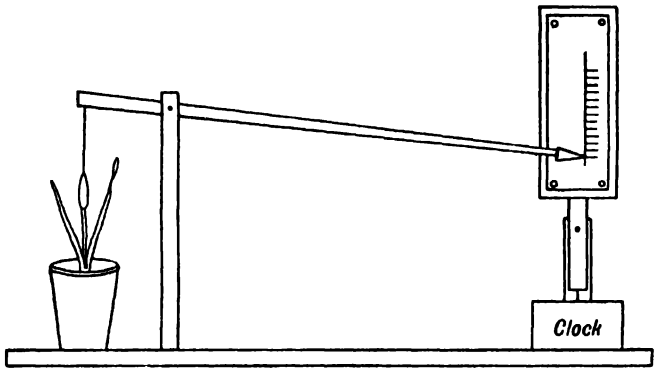


FIG. 243.

a horizontal line marking each hour is obtained. By spraying with gum fixative at the conclusion of the experiment, the record can be made permanent. The actual amount of growth of the stem during any one hour is then calculated by dividing the number of mm. in the interval between the two horizontal lines concerned by the number expressing the degree of magnification produced by the lever.

The tip of the plant stem is attached to the lever by a thread and, to avoid damage to the delicate growing point, it is advisable to choose for experiment the flower stem of a Narcissus, Polyanthus, Dandelion or Hawkweed, in all of which growth occurs below the " flower head " to which the thread can be fastened. The plants used

should either be grown from the start in pots or, if transplanted, be given sufficient time to recover from the effects of transplantation. In all experiments, it is necessary to give the plant an ample supply of water to maintain turgidity, or growth will be affected.

From actual performance tests made in the laboratory, it was found that the following effects could be investigated.

404. TEMPERATURE EFFECT

(*a*) Variation in daily and nightly temperatures is found to be followed by increased growth rate during the day and retarded growth rate at night. The retarding effect of light on growth rate does not prevent this general effect being shown, though it is more marked when day temperatures are high and night temperatures are low, e.g. in spring when the laboratory is artificially heated by day.

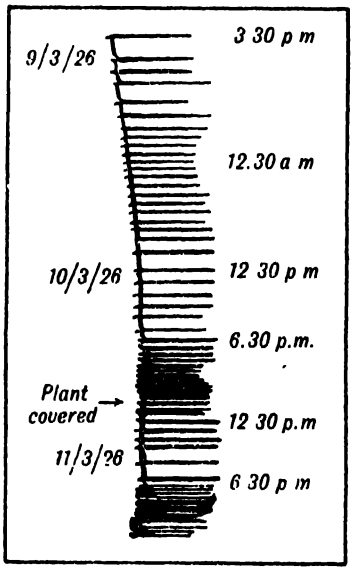


FIG. 244.

For example, see Fig. 244, a record obtained by using a Narcissus stem and magnification of four times.

(*b*) Close correspondence of growth rate with varying temperature may be shown by excluding the effect of light. For this purpose, the plant should be enclosed in a cardboard box with a hole at the top, to allow for unimpeded passage of the thread. Hourly readings of the temperature should be made.

For example, see Fig. 245, a record obtained by using

magnification of eight times. The slight "lag" in the response is due to growth in a Narcissus stem occurring, as in most Monocotyledons, at the base of the stem below the ground-level and hence not being immediately affected by changes in air temperature. With a Dandelion stem, in which growth occurs just below the "flower head," this lag is not so apparent.

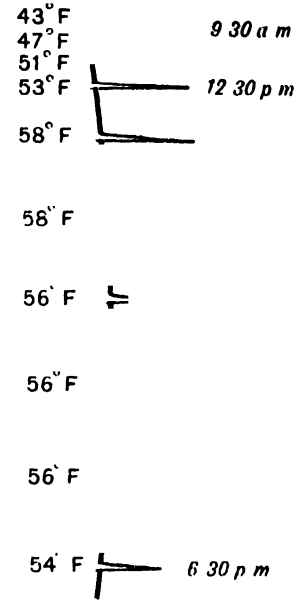


FIG. 245.

405. EFFECT OF VARYING LIGHT INTENSITY

To show this, records should be obtained by placing the apparatus, first, against a window with an easterly aspect; secondly, against one with a westerly aspect. If the plant is placed in such a position that direct sunlight leaves or reaches the plant precisely at noon, the following effects can be obtained:

(*a*) With easterly aspect, in spite of increasing temperature, retardation is noticeable up to noon, followed by immediate increase in growth rate so soon as direct sunlight leaves the plant.

(*b*) With westerly aspect, the growth rate increases up to noon and then decreases during the afternoon hours when direct sunlight falls on the plant, and this occurs in spite of the high temperature.

For example, see Fig. 246, showing retardation during the afternoon in growth rate of a Hawkweed stem with westerly aspect (using magnification of eight); also

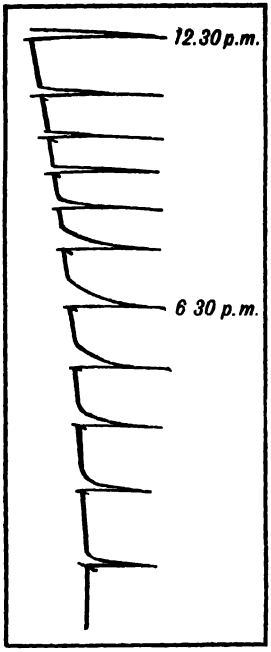


FIG. 246.

Fig. 247 for representative graphs obtained by plotting magnified growth in mm. (Vertical distances give the amount of growth for each hour.)

Nos. 1 and 2 obtained with easterly aspect.

Nos. 3 and 4 obtained with westerly aspect.

The best records are obtained on fine summer days when a spell of unbroken sunshine is ensured, though the main effect will be apparent even in unsettled weather.

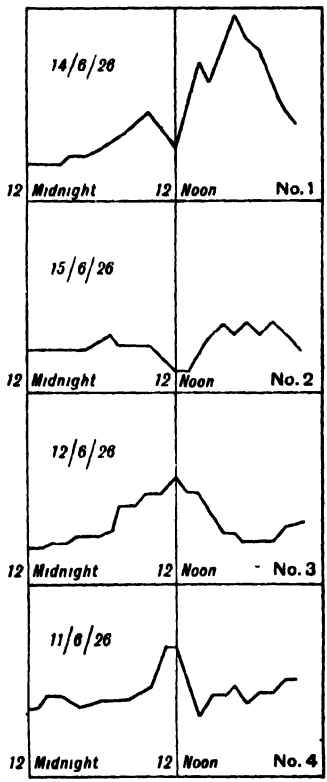


FIG. 247.

406. RATE OF INCREASE IN AREA OF A LEAF

Cambridge, 1923

The rate of increase in area of leaves of growing plants can be determined by the following photographic method. A species with flat, unwrinkled leaves, e.g. kidney (French) bean, should be selected; a young leaf,

still attached to the growing plant, is placed on a sheet of sensitised photographic paper, supported on a piece of glass or other convenient platform, and is covered by another glass plate that is lightly pressed down so as to flatten the leaf as perfectly as possible. The whole is then "exposed" to a good light, and the photographic paper subsequently "developed" and "fixed." The exact area of the leaf is thus left white on a black ground, and the surface mapped out can then be measured by any of the methods for determining areas. By repeating the operations with the same leaf on each succeeding day, the increase in area can be measured with considerable accuracy. The whole series of prints at the end of, say, a fortnight, affords a very graphic demonstration of the rate of growth of these important plant organs.

PLANT PATHOLOGY

407. MATERIAL AND APPARATUS

Eric Ashby

There is no difficulty in finding material for experiments in plant pathology, and the apparatus is simple and need not be expensive.

After the usual botanical equipment, a clean room is the first essential; a room which is not used for chemistry, and in which food and clothing must never be left. For sterilising media, an autoclave, in which water boils under pressure, is most useful, although prolonged heating in a steamer will suffice; e.g. a deep household pot fitted with a lid and a slightly shallower inner vessel will serve. Glass dishes can be sterilised in an ordinary gas oven, heated to about 170° C. An incubator in which cultures can be kept at about 25° C. is also valuable, but this can be replaced by a clean well-made cupboard, standing over a radiator.

The autoclave and the incubator are the only expensive items, and neither is essential for the plant pathologist.

Indeed, very much serious work is done in tropical countries without either of them.

A large number of Petri dishes of different sizes, test-tubes, cotton wool and inoculating needles of chrome-nickel wire, complete the list of apparatus required.

Much of the material can be found in the field, but it will be necessary to obtain a few stock cultures for experimental work. These can be bought from the National Collection of Type Cultures, Lister Institute, London, S.W.1. On receipt of these cultures, they should be transferred to four or five "slopes," and reinoculated on to new medium every three months; in this way they can be kept indefinitely. The cultures recommended for this work are:

Rhizopus nigricans.
Fusarium sp.
Monilia fructigena.
Botrytis cinerea.
Aspergillus sp. (which gives *perithecia*).

A number of useful textbooks on plant pathology have been published.[1] These would be useful if it were wished to augment the work suggested here.

408. METHODS AND TECHNIQUE

Eric Ashby

Work must begin with the methods and technique of culture, and the phenomena of growth.

Media.—Two media will be required: potato agar and malt agar. The first is prepared by peeling and cutting up 250 grams of potatoes, boiling them for one hour, and squeezing the mush through muslin. To the mush, 20 grams of agar are added, and the volume is made up to 1 litre. The operation of squeezing through muslin is

[1] Harshberger, *Mycology and Plant Pathology*, London, 1917. Heald, *Manual of Plant Diseases*, New York, 1926. Duggar, *Fungus Diseases of Plants*, Boston, 1909. Brooks, *Plant Diseases*, London, 1928.

messy, but only in this way can one be sure of a plentiful supply of cellulose in the medium.

Malt agar is easier to prepare. About 20 grams of malt and 20 grams of agar are added to 1 litre of distilled water, in a flask.

The flasks containing the media must then be plugged with cotton wool, and heated in the autoclave or in a steam oven, to dissolve the materials.

Medium is kept in test-tubes plugged with cotton wool; different colours can be used for different media. The plugs are made by rolling up tightly oblong strips of wool, and screwing them into the test-tube, where they must hold firmly. The medium is then poured into the tubes. Some should be two-thirds full; these are used for pouring on to plates for plate cultures. Others receive just enough to make "slopes" (Fig. 248). The tubes are then plugged and sterilised. A tube whose plug has come into contact with the medium is not safe to use, and the plug should be changed before the tube is sterilised.

Half an hour in the autoclave at a pressure of two atmospheres (121·4° C.) will suffice for sterilisation. If the tubes are to be sterilised by steaming, half an hour on three successive days will be necessary in order that bacteria which are in the resting condition on the first day are killed on succeeding steamings. On no account must the plugs be allowed to get wet. After sterilisation, the "slopes" are left to set slantwise. The medium is then ready for use.

Cultures are made on "slopes" or on plates. The plates are sterilised by heating to about 170° C. in a gas oven, or by prolonged steaming. The medium in one or more of the tubes is melted in a beaker of water, and poured into the sterile plate, care being taken to lift the lid as little as possible. The medium should be at a temperature just above its point of solidification, and the plates should be quite cool before the medium is poured into them. When the medium is set, it is ready for inoculation.

Inoculation.—The best inoculating needle is a piece of stout chrome-nickel wire, about 1½ in. long and slightly hooked at the end. It can be set in a piece of glass rod, though a cheap metal holder is more convenient. Wooden holders are useless, since they cannot be sterilised properly. The wire and holder are sterilised before inoculation by heating to redness. The needle is allowed to cool,

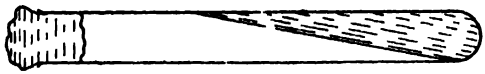


FIG. 248.

and a piece of the fungus is picked out and set in the new medium as quickly as possible. Unless cultures are sporing, a small piece of mycelium and agar must be transferred to the new medium when making an inoculation. This process should be practised until cultures can be made which will not become contaminated.

409. THE SYSTEMATIC STUDY OF PLANT DISEASES

Eric Ashby

The standard procedure is as follows :

1. Describe the symptoms.
2. Inoculate from the diseased material on to a decoction of the plant medium.
3. Separate the organisms which appear from this inoculation.
4. Re-inoculate healthy material with the various organisms, to find which reproduces the same symptoms.
5. Re-isolate the same fungus from the successful inoculation.
6. Identify the fungus.

(1) In plant diseases, the symptoms are a function of the plant and not of the parasite. A plant will react towards several different diseases in exactly the same way. Symptoms have not, therefore, the same value in diagnosis as they have in animal pathology. The

commonest signs of disease are discoloration and perforation of the leaves; wilting or dwarfing of the whole plant; hypertrophies; and the rotting and shrivelling or shedding of fruits or leaves.

(2) A part of the plant which is obviously diseased is sterilised on the outside, with formalin or methylated spirit, to kill chance organisms. An inoculation is taken from the inner side of the diseased part. This region is chosen because the parasitic fungus is required as pure as possible, and a host of saprophytic fungi follow the parasite and occupy the regions it has attacked. Where it is possible, a decoction made from the host plant material is used. This, however, is not essential.

(3) The organisms present in the inoculations are separated in the following way: the fragment of diseased material on the needle is mixed into a Petri dish containing medium which is still liquid, but which is below the lethal temperature for the fungus. (About 40° C. is safe.) The needle, with a drop of this infected medium, is mixed into a second plate of medium at the same temperature. This process can be repeated four or five times, each plate receiving a more dispersed dilution of the original inoculation. The plates are then incubated at about 25° C. After a couple of days, various organisms will have appeared; they can then be separated, and transferred to different plates. The only serious difficulty in the process is the separation of the fungus from bacteria, and this can often be effected by growing the fungus on a slightly acid medium, or on plain agar.

(4) Probably one of the organisms obtained from the inoculations has caused the disease, and the next step is to discover which of these it is. Samples of healthy plants, or parts of plants, must be inoculated with pure cultures of all the organisms which have been separated, except, of course, the obvious saprophytes. If the disease-causing fungus really has been isolated, the disease will reappear in one of the inoculations, and the same symptoms will recur.

(5) To put the investigations beyond doubt, the pathogenic fungus must be re-isolated. This time it should be in pure culture.

(6) The last stage in the investigation of a disease is the identification of the fungus. The classification of many of the groups is so nebulous that identification is often the work of a specialist.

Ability to work on fungal diseases necessitates training in the technique outlined above. There will not be time in the laboratories to practise these methods fully; but the principles underlying them can be illustrated by a few simple experiments.[1]

410. THE "DAMPING-OFF" OF SEEDLINGS *PYTHIUM DE BARYANUM*[2]

Eric Ashby

Pythium de Baryanum is a typical non-specialised parasite; it commonly attacks the hypocotyls of seedlings at the ground-level. The infection is derived from the ground or from neighbouring plants. The hyphæ apply themselves to the epidermal walls; the processes grow through and branch repeatedly inside. The mycelium occupies all the tissues of the hypocotyl except the xylem; usually the cortex is the most strongly attacked. Since the seedling depends upon the turgor of its cells for support, it soon collapses and dies.

Under certain conditions, the richly branched mycelium bears reproductive organs, and from an inspection of these the fungus may be identified (Fig. 249).

The progress of the disease can be studied very easily in the laboratory. Two sets of cress seedlings are grown in large flower-pots, two-thirds filled with garden soil. One set is kept fairly moist, but cool and well ventilated;

[1] For some of the experiments described the author is indebted to Prof. W. Brown's Pathology Course in the Imperial College, also to Miss E. H. M. Farries, for helpful criticism and advice.

[2] A full description of the disease is given in Sorauer, *Handbuch der Pflanzenkrankheiten*, II, p. 125.

the other should be warm, moist and partly covered with a sheet of glass. In less than ten days, the first set of seedlings will have reached a height of about 2 in., while many of the second set will be found prostrate. Examination of the withered part of the hypocotyl of these will reveal a dense interweaving of *Pythium*.

The effect of thick sowing can be demonstrated concurrently by giving one set of pots a normal seeding and a corresponding set an excessive seeding, both sets being kept in warm, moist external conditions.

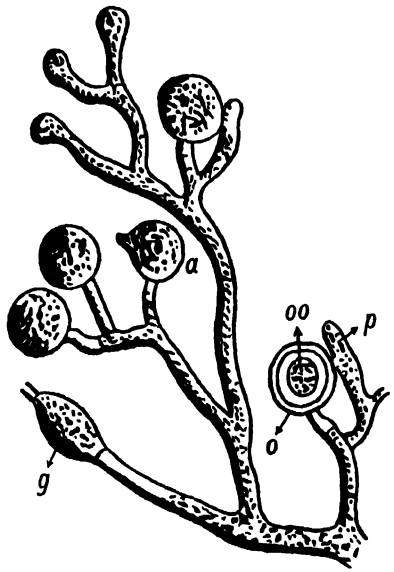


FIG. 249. —*Pythium de Baryanum*. *a*, young zoosporangium; *p*, antheridium; *o*, oogonium; *oo*, oosphere; *g*, intercalary cell. (After Sorauer.)

A third experiment should be included in this series to demonstrate that "damping-off" is a soil-borne disease. Sufficient soil for a set of pots should be sterilised in an oven at 210° F. for one hour. After cooling, the soil is moistened with sterile water and the pots are given the same rate of seeding as the control pots in which untreated soil is used. Both sets should be kept warm and moist.

The next task is the isolation of the fungus from the diseased tissue. Pieces of infected hypocotyl are put on to a plate of plain agar medium. The medium is prepared by dissolving 15 grams of agar in 1 litre of water, and sterilising the solution. On plain agar the bacteria, which are invariably present, cannot flourish, while the

Pythium forms a very thin mycelium over the surface. Under the microscope, a piece of agar containing the growing edge of the medium can be picked out with a sterile needle, and transferred to a plate of potato agar, on which medium *Pythium* will grow vigorously. If the culture is not yet free from bacteria, a second transfer must be made. Eventually, a pure culture should be obtained, which can then be examined and identified. As a final test, some healthy seedlings, grown in a sterilised soil, can be re-infected with the pure culture by watering with a spore suspension.

The procedure outlined above embodies the essentials of etiology, for it includes isolation of the pathogenic fungus from the diseased tissue, its purification and culture. *Pythium* is always present in the soil, and the material can be prepared in just over a week.

411. BROWN ROT OF APPLES. *MONILIA FRUCTIGENA*

Eric Ashby

The apple is prey to a great many diseases, both physiological and parasitic. If the skin is broken in any way, the tissues are open to the attack of many non-specialised parasites which cannot ordinarily gain entrance. The progress of the disease caused by *Monilia fructigena* can be observed very closely, for the student himself can inoculate apples with the pathogenic fungus.

The outside of a number of apples should first be sterilised by immersion in 95 per cent. alcohol for a few minutes, and then washing with sterile water. They are inoculated in the following manner.[1] A small cork borer is sterilised and pushed about half a centimetre into the apple. The cork borer is withdrawn, together with the piece of apple it has cut out, and a fragment of mycelium from a fresh culture of *Monilia fructigena* is inoculated

[1] Granger, K., and Horne, A. S., "A Method of Inoculating the Apple," *Ann. Bot.*, 38, p. 213, 1924.

into the pit. The portion of apple tissue is then pushed back into place by a sterile glass rod passing through the middle of the cork borer. To prevent other organisms entering the wound, the cut is then sealed by pouring a little paraffin wax over it.

Exactly the same process must be repeated with the control apple ; except that a sterile needle is rubbed into the pit, instead of a needle bearing living hyphæ. The two apples are kept under bell-jars, at room temperature. In a few days, the brown rot associated with *Monilia* will appear, and rapidly spread over the apple ; and after about a fortnight, fructifications will follow. The control apple ought to remain sound. All stages of the disease can be followed easily, and since the fungus is in pure culture, one should be able to reisolate it without difficulty, by planting out an inoculum taken from a part of the apple recently infected.

412. "FOOT ROT" OF BARLEY. *HELMINTHOSPORIUM SATIVUM*

Eric Ashby

The symptoms of this very common disease of barley are "damping-off" of the seedling, a black coloration at the base of the plant and "striping" of the leaf. By the following method, the nature of the disease can be investigated.

Viable barley seed is sterilised by immersion in a 0·1 per cent. solution of mercuric chloride, and subsequently washing in sterile water. It is then germinated in a large sterilised dish, between layers of blotting-paper soaked in sterile water. About eight seedlings are transferred to a large boiling tube containing a wad of cotton wool at the bottom, about one-fifth full of Knop's solution,[1] and plugged at the top with cotton wool. The boiling tube and its contents must be sterile.

[1] $Ca(NO_3)_2$, 1 gm. ; KCl, 0·25 gm. ; $MgSO_4$, 0·25 gm. ; KH_2PO_4, 0·25 gm. Trace of ferric chloride. Water (dist.), 1 litre.

To the solution in the boiling tube are added a few drops of a spore suspension, in sterile water, of *Helminthosporium sativum*.[1] The tube is then incubated at about 25° C. for some days. The symptoms of "foot rot" will rapidly appear, and the diseased parts of the plants should be carefully drawn.

413. BROWN RUST OF WHEAT. *PUCCINIA TRITICINA*

Eric Ashby

Rust fungi are regarded as the most highly specialised of plant parasites. They are so selective in their food requirements that they cannot be grown on artificial nutrients and must be cultivated on living plants. Another feature is that single species occur in nature in several biological races or forms. These races are morphologically indistinguishable, but are distinguished on physiological grounds, viz. on the restricted range of host plants which they are capable of parasitising. Several distinct biological forms of *P. triticina* occur in North America and in Europe.

Brown rust of wheat is found most commonly late in the season, just before harvest. Leaves showing uredospore pustules should be collected, dried in air and stored between leaves of paper in a cold room.

Wheat seedlings for inoculation should be grown in 3-in. flower-pots at the rate of five seedlings per pot. When the second leaf is ½ in long, the seedlings should be inoculated.

Inoculation.—(i) The leaves are sprayed with sterile water, and each is rubbed gently with the forefinger to ensure that the surface is completely wetted. (ii) Each leaf is painted with a suspension of uredospores made by scraping the spores from the dried material into a small quantity of sterile water. (iii) The pots should be covered

[1] To be obtained from the Lister Institute, London, S W.

with a glass lamp chimney of convenient size, roofed over with fine muslin, which should be sprayed with water at this stage. The pots are placed on a tray of wet peat moss and covered with a large bell-jar. The object of this procedure is to ensure that the inoculated plants are maintained in a saturated atmosphere for forty-eight hours after inoculation. At the end of that period, the bell-jar is removed, but the lamp chimney is retained throughout the period of the experiment.

Yellow discoloured patches will appear on the leaves after six or seven days at 20° C.,[1] and later the pustules of uredospores will break through the epidermis.

Should difficulty be experienced in obtaining material of *P. triticina*, a similar experiment could be carried out with the Hollyhock Rust, *P. malvacearum*. Although the conditions of infection have not yet been worked out in detail as for cereal rusts, it is known that artificial inoculations take readily. *P. malvacearum* can be found in any garden and a supply of plants for inoculation can be easily grown. Seed should be sown in sand in a seed box and kept warm. When the seedlings are at the two-leaf stage, they should be pricked out in small pots, after which they can be hardened off. Inoculations could conveniently be made when the leaves are 2 in. across. The pustules are brown, and consist of little heaps of teleutospores which arise from a pad of mycelium. They should be used for germination experiments.

Chrysanthemum Rust, caused by *P. chrysanthemi*, could be studied in the same way. It is found wherever chrysanthemums are grown under glass, especially on the variety "Winter Cheer." Uniform plants for inoculation are best obtained by taking cuttings of young shoots arising below the soil-level on a chrysanthemum plant which has been cut back. Such cuttings should be about 4 in. long. They will root readily in soil

[1] Gassner, G., and Appel, G.O., "Untersuchungen über die Infektionsbedingungen der Getreiderostpilze," *Arbt. a. d. Biolog. Reichsanst. f. Land. u. Forstwirtshaft*, p. 417, 1928.

if kept in a closed frame or covered with glass. Observations should be made throughout the period of development.

Rusts are a most interesting group for field study. They are very common in the summer-time, on all sorts of plants. They can be easily recognised under the microscope by their reproductive organs, and their biology is of exceptional interest. For identification of specimens, and a description of their biology, the reader is referred to Grove's monograph.[1]

414. SOFT ROT OF CARROT. *BACILLUS CARATOVORUS*

Eric Ashby

The soft rot of carrot will serve as an introduction to bacterial diseases. *Bacillus caratovorus*[2] is the cause of the common soft rot of vegetables: turnips, carrots, celery, etc. The bacillus is incapable of penetrating the uninjured tissues of the host plant; it must enter through wounds already present in the epidermis. Attack is characterised by a rotting of the tissues into a translucent mass, which often smells very strongly. The rot is caused by an enzyme, pectinase, which dissolves the middle lamella of the cells, thus disorganising the tissues.

The procedure is as follows: A clean carrot is washed for 10 min. in 0·1 per cent. mercuric chloride, and then rinsed thoroughly with sterile water. This suffices to sterilise the outside of the carrot. Two slices are cut from the carrot, and put into two sterile Petri dishes, with a few drops of sterile water. One slice is inoculated with *Bacillus caratovorus*, and the other left uninoculated as a control. Both dishes are incubated at 25° C. In a very short time, the rot associated with this bacillus

[1] Grove, *The British Rust Fungi*.

[2] To be obtained from the Lister Institute, London, S.W.

will appear. A portion of the diseased tissue should then be transferred to a plate of medium made from carrot juice and agar. Upon this medium the growth of the bacillus can be followed, and an opportunity of observing the microscopic characters of bacterial cultures is afforded. As a further exercise, the bacillus can be inoculated on to celery, bulbs and other soft parts of plants.

Note.—Cultures of *B. caratovorus* sometimes lose their pathogenic quality. If this quality has been lost, it can often be revived by inoculating the bacillus time after time on to fresh pieces of carrot.

415. WOUND REACTIONS

Eric Ashby

The underground parts of plants are protected by a resistant epidermis, or by several layers of cork; and a great many disease-causing fungi cannot enter the plant except through wounds. Many plants are able to regenerate a new covering layer beneath a wound, and it may not be out of place to illustrate the process by which this takes place.

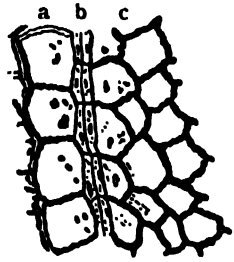


FIG. 250. — Section across regenerated wound of potato tuber: *a*, dead cells at the surface; *b*, meristematic tissues; *c*, parenchyma of the tuber.

A piece of potato tuber, cut with a sterile scalpel, is left for a few days in a warm, damp atmosphere, e.g. a sterile dish lined with damp blotting-paper. Sections perpendicular to the wound surface are then cut, and can conveniently be stained with hæmatoxylin. It will be seen that regeneration of periderm has taken place immediately *under* the wound surface.

Note.—Not all varieties of potato exhibit this regeneration. The variety "King Edward" is known to give satisfactory results.

416. POTASH HUNGER OF POTATOES

Eric Ashby

It is often thought that plants which are being starved in some mineral constituent merely exhibit a stunted and feeble growth. This, however, is not the case; for, in addition, a number of abnormal and pathological characters appear. The effect of inadequate nutrition may often give rise to symptoms strikingly resembling the symptoms of parasitic diseases. The following simple experiment will illustrate this point.

Two solutions are prepared: de Crone's normal solution[1] and the same solution without potash, potassium nitrate being replaced by magnesium nitrate. If young potato plants are grown in sand cultures, watered, some with solution one, and some with solution two, a marked difference in the appearance of the two sets of plants will be observed. The seedlings starved in potash will have yellow leaves, weak stems and other abnormal symptoms. Since the conditions of growth are the same for the two sets, except for the absence of potash in one, the pathological characters can be attributed to potash starvation. Arising from the use of a fertiliser deficient in potash, an outbreak of this "disease" occurred in parts of America in 1916, and it was found that the application of potash salts "cured" the outbreak.

417. MOSAIC OF TOBACCO

Eric Ashby

Virus diseases are not suitable for demonstration in a school course. Prof. Brown, however, suggests that the mosaic of tobacco is so striking and so easy to produce that it would be of interest to include it here.

If a small quantity of sap from a tobacco plant affected with virus is inoculated into a healthy plant, the healthy

[1] KON_3, 1 gm.; $CaSO_4$, 0·5 gm.; $MgSO_4$, 0·5 gm.; $Ca_3(PO_4)_2$, 0·25 gm.; $Fe_2(PO_4)_2$, 0·25 gm.

plant will develop the disease. Sometimes it is only necessary to touch a healthy plant with sap from a diseased plant for the infection to be transmitted. Culture methods and microscopic examination reveal no organism in the infected sap, nor is the " infective principle " held by a Chamberlain filter. If it is an organism at all, therefore, which causes the disease, it must be very minute.

Four hypotheses have been put forward to account for the mosaic diseases. It has been suggested that the infection is caused by a very small bacterium. For this view there is no conclusive evidence at all. Secondly, there is a theory that an enzyme is the cause of the disease, since the virus resists antiseptics, and is inactivated at the same temperatures and by the same substances as are enzymes. But this view, too, does not accord with all the data. There is, thirdly, the suggestion that the disease is due to a specific *virus* which upsets the metabolism of the cell; and recently it has been thought that a protozoon causes the infection. The question remains open, and the problem of mosaic diseases occupies the chief place in modern pathological research.

If it is proposed to observe this disease, tobacco plants must be grown[1] from seed some time before they are required. Seed is sown near the surface of the soil, so that it is only lightly covered, and kept at a temperature of 60° F. The seedlings are pricked out at the two-leaf stage and potted up when the leaves are 2 in. across.

There are various methods of transferring the virus principle.

(i) A small piece of tobacco leaf suffering from mosaic is crushed between the fingers, an incision is made in the stem of a healthy plant and some of the crushed tissue is put into it. The wound is bound up with lead foil. In a short time, the effect of the disease will appear in the leaves, which become spotted.

[1] There are Government regulations with regard to the growing of tobacco in England. One is allowed to grow only a few plants. It would be advisable to communicate with the Board of Agriculture if it is intended to try this experiment.

(ii) The virus can be easily extracted from the leaves. To prepare an extract, fresh or dried leaves are ground up with silver sand. To the powder distilled water is added; about half of the weight of leaf tissue is sufficient. The extract is then filtered. In this form it can be kept for a considerable time.

This extract can be introduced into the plant by a pin-prick, by merely injuring the hairs of a healthy leaf in painting the extract on the surface with a camel-hair brush, or by touching a healthy leaf with fingers contaminated with the extract. The symptoms will appear not only in the leaves which have been inoculated, but in the young developing leaves also. Leaves should be dried for use the following year.

Note. — Prof. Brown, of the Imperial College of Science, London, has kindly consented to send an initial sample of virus to any school wishing to carry out these experiments.

RESPIRATION

418. DEMONSTRATION OF THE RESPIRATION OF ROOTS

Birmingham

The roots of wheat seedlings were immersed in a weak solution of congo red, which turns purple in the presence of weak acid. The formation of carbonic acid, owing to the evolution of carbon dioxide by the respiring roots, causes a colour change which is contrasted with a control solution without seedlings.

419. MODEL ILLUSTRATING THE ACTION OF GUARD-CELLS IN REGULATING THE APERTURES OF STOMATA

O. H. Latter

The model consists of two pieces of inner tube of a bicycle tyre, each about 1 ft. long. Both ends of each

piece are securely closed with rubber solution for about 1 in. of their length. An ordinary bicycle valve is inserted about half-way along the intended outer side of each piece, and to the intended inner side of each is cemented a strip of rubber sheeting to represent the thickened wall on that side of each guard-cell. The closed ends of the two are then firmly united face to face with rubber solution. When deflated, the tubes are in contact along their length—the guard-cells are flaccid, the stoma closed; when inflated, the tubes bow apart—the guard-cells are turgid, the stoma open.

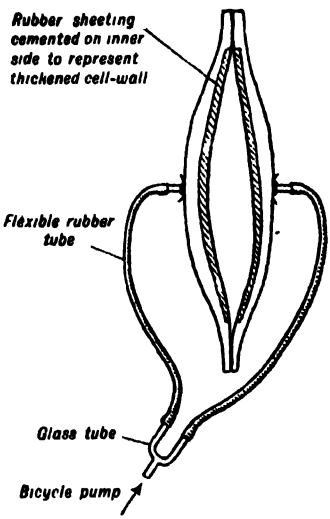


FIG. 251.

TROPISMS

420. THE EFFECT OF ALKALINITY ON SPIROSTOMA

J. T. Saunders

If two watch-glasses, filled, one with distilled water, the other with "hard" tap water, have a few Spirostoma added to each, we can observe some interesting differences. The watch-glasses should be placed in a moist chamber, so as to prevent evaporation, for the experiment may take some time. Those in the distilled water are unaffected and go on swimming round, but after a time, varying from two to twelve hours, those in the hard water fall to the bottom and become pear-shaped. After struggling on in this pear-shaped condition for a little while, the animals finally burst and disintegrate. The

reason for this difference of behaviour is that the hard water, having a large surface exposed to the air, will contain only as much carbon dioxide as it will dissolve at atmospheric pressure. This is very little indeed, and the alkalinity of the "hard" water, due to the carbonates of calcium and magnesium it contains, reaches *p*H 8·0 or more, which is sufficient to cause the death of the Spirostoma. In Cambridge, Spirostoma sometimes occur in ponds in enormous numbers in the winter. If we examine the water of these ponds in the winter, we find that the water is only a little on the alkaline side of neutrality. When spring comes, the Spirostoma disappear, and this disappearance coincides with the growth in the pond of vegetation, which, by its photosynthetic activity, removes the carbon dioxide from the water faster than it is produced by decomposition in the mud, and so raises the alkalinity of the water to a point fatal to the Spirostoma. In other districts, Spirostoma may occur all the year round; the habitat in this case will be a pond filled with leaves. Here the Spirostoma can shelter beneath the leaves in a water reduced in alkalinity by decomposition of the organic matter.

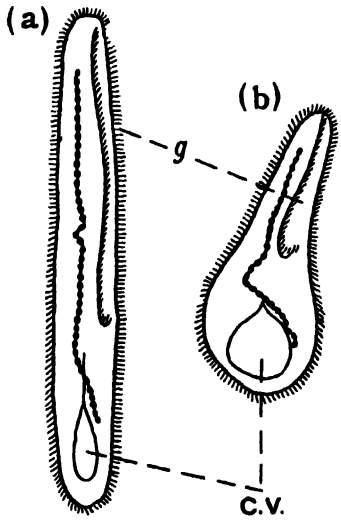


FIG. 252.—(*a*) Normal shape of Spirostomum when fully extended. (*b*) Pear-shaped form produced by keeping the animal for a few hours in water that is slightly alkaline (*p*H 8·5 or more). Note that the contractile vacuole is greatly enlarged. (*g*) Oval groove; (*c.v.*) contractile vacuole.

Colpidium will be destroyed in the same manner as Spirostomum if it be exposed in a watch-glass, but the

destruction takes longer, as a rule, depending on the alkalinity produced by the exposure. Both in the case of Colpidium and Spirostomum, it should be observed that the pressure inside the body is increased. This

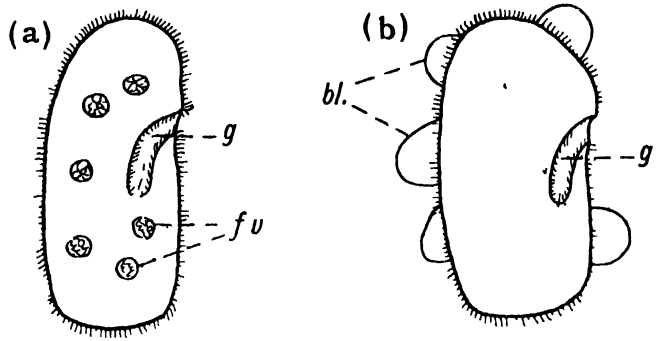


FIG 253 — (*a*) Colpidium, normal appearance (*b*) Appearance after exposure in a watch glass. (*g*) Oval groove (*f v*) Food vacuoles. (*bl*) "Blebs"

increase of pressure is made manifest in the case of Spirostomum by the pear-shaped appearance and the permanently distended contractile vacuole, and in Colpidium by the appearance of "blebs" (see Fig 253). The rise in alkalinity of the medium has evidently affected the permeability of the ectoplasmic covering.

421. PARAMECIA AND ALKALINITY

J. T. Saunders

Paramecia are not so sensitive to changes in alkalinity as Spirostoma, but even a slight alteration in the medium may cause them to leave it. To show how slight these changes may be, support a cover-slip on wax[1] "feet," so as to leave a space between the cover-slip and the slide of

[1] The best wax to use for this purpose is adhesive wax. It may be purchased from British Drug Houses, Ltd, under the name of "Sira" adhesive wax. It is convenient to warm the wax slightly and to dig out small pieces to form the supports with the corners of the cover-slip. Use strong cover slips (No. 3 thickness).

0·5–1·0 mm. (see Fig. 254). Now remove some Paramecia from the culture with a pipette and run them under the cover-glass so as to fill half the available space. Again fill a pipette with Paramecia and culture fluid, but before injecting it into the cover-slip, squirt it into a watch-glass, leave it for a few minutes, and then suck it up again into the pipette. Now inject the contents of the pipette under the same slide, so as to fill the remaining space. If the experiment is properly done, the Paramecia will almost immediately leave the fluid which has been exposed in the watch-glass and collect in the half which has not been exposed (see Fig. 254).

422. PARAMECIA AND ACIDITY

J. T. Saunders

Paramecia are placed under a cover-slip supported, as before, on wax feet, and allowed to stand for a few minutes to settle down. Then a drop of water, saturated with carbon dioxide,[1] is placed at one end of the cover-slip,

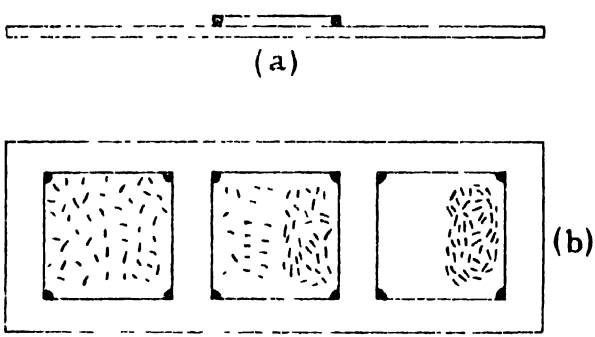


FIG. 254. (*a*) Side view of a cover-slip supported on a slide by wax feet. (*b*) Three stages in the migration of Paramecia from culture liquid which has been exposed (left-hand side) into liquid which has not been exposed (right-hand side).

when all the Paramecia, which have been previously swimming at random, will be seen to head straight for the

[1] Water saturated with carbon dioxide is very easily prepared in an ordinary "Sparklet" syphon.

attractive drop. They gather round the edge of the drop in a ring. After a little while, the attractiveness seems to disappear, and the ring breaks up. Other acids, such as dilute acetic and butyric (N/10), work equally well. Butyric is very good, and if this acid is used, a double ring appears a minute or so after adding the drop of acid. The inner ring is formed of corpses of Paramecia which have over-indulged and gone too far; the outer ring is living, and consists of the more temperate forms which know their limitations and retreat as the acid slowly diffuses into the culture fluid under the slide.

423. FLAGELLATES OR COLPIDIA AND ACIDITY

J. T. Saunders

The sensitivity to changes in the environment is very clearly demonstrated by the behaviour of Flagellates and Colpidia. A thick culture of Flagellates (from the Spirostomum culture that has gone wrong), or of Colpidia, is run under a square cover-slip, supported on wax feet, and is placed in a moist chamber to prevent evaporation at the edge. After a little while, the Flagellates, or the

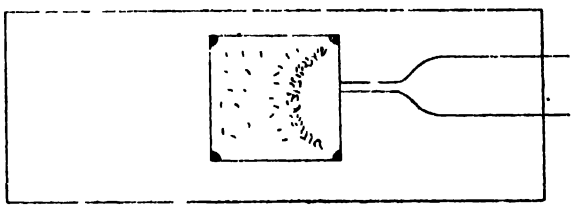


FIG. 255.—Paramecia attracted to the edge of a drop of dilute acid inserted under the edge of the cover-slip.

Colpidia, collect at the outer edges of the cover-slip; gradually they retreat inwards and a ring is formed (see Fig. 256). This ring is composed of vast numbers of animals, all congregated in a small area of the culture fluid where, presumably, things are exactly to their liking.

We can explain this ring formation at the edges of the cover-glass in the following manner. The medium in which they are living contains an amount of carbon dioxide which is considerably in excess of that which will dissolve at atmospheric pressure. Consequently, at the edges of the cover-slip, carbon dioxide rapidly diffuses out, and so renders the liquid here more alkaline. If we sup-

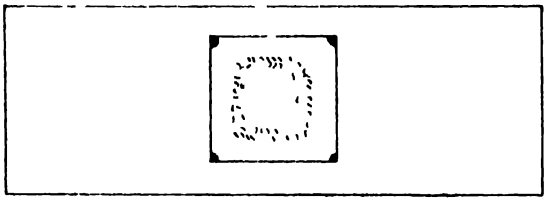


FIG. 256.

pose that the culture liquid is a little too acid for the animals, they will be attracted outwards by the alkaline water at the edges, and will halt as soon as they find it too alkaline. The diffusion of the carbon dioxide from the edges sets up an alkaline-acid gradient. The ring is due to the animals taking up a preferred position on this gradient. We can prevent the gradient formation by exposing the cover-slips in an atmosphere of carbon dioxide, and this also prevents ring formation. We can also prevent the gradient formation by exposing the culture liquid to air so as to bring its dissolved gases into equilibrium with the atmosphere. If this exposed culture liquid and its fauna be placed under the cover-glass, no ring formation occurs.

424. REACTION TO CHANGE OF TEMPERATURE

J. T. Saunders

In mixed cultures of Flagellates and Colpidia, or of Colpidia and Paramecia, different sensitivities, or a lack of sensitivity of one animal, may be often noticed. There is a very striking difference in the sensitivity of Para-

mecium and Colpidium to raising the temperature of the culture fluid. Place a mixed culture of Paramecium and Colpidium under a supported cover-slip and put this on the stage of a microscope. Remove the condenser and the mirror from the microscope, and place underneath the stage, fairly near to the slide, a carbon filament electric light bulb. The heat from this bulb warms the slide, and the Colpidia are very quickly immobilised and killed. The Paramecia remain quite lively. Advantage is sometimes taken of this difference of sensitivity to heat to rid a Paramecia culture of Colpidia. If the culture be raised to a temperature of 25–30° C. for a few minutes, all the Colpidia are destroyed, while the Paramecia are left unharmed.

425. A METHOD FOR PROJECTING SLIDE EXPERIMENTS ON A SCREEN

J. T. Saunders

Experiments performed on slides under cover-slips can be projected on to a screen and so seen by a large class,

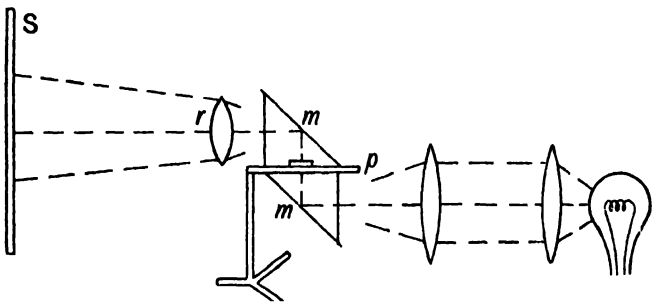


FIG. 257.—Diagrammatic representation of the method used for projecting the experiments on to a screen. *m* and *m*, mirrors, fixed at an angle of 45° to the plate of glass, *p* ; *r*, the projection lens of the lantern ; *S*, screen. The slide is placed in an horizontal position on the plate, *p*.

if a lantern with a powerful source of light is available. They are projected as a lantern slide, but it is necessary to arrange that the carrier shall be horizontal, not vertical

as is usual. To do this we can use a simple apparatus constructed of a piece of thin plate glass and two mirrors, as shown in Fig. 257.

It will be necessary, of course, to raise the projecting lens of the lantern a distance equal to that separating the surfaces of two mirrors. The mirrors absorb a good deal of light, hence the need of a powerful source of light. If an arc-lamp is used, precautions must be taken to cut out the ultra-violet rays, or the animals will be quickly destroyed. A trough filled with quinine dissolved in dilute sulphuric acid works very well for this purpose.

APPENDIX I

CONVERSAZIONE NOTES AND EXPERIMENTS

THE following notes have been compiled from programmes sent by City of London School, Dean Close, Repton, Rugby and Whitgift School. They show that, with certain reservations in chemistry on account of the dangers of fire, explosion, splashing with acid and the liberation of noxious fumes, almost any ordinary demonstration experiment is suitable, though, of course, it should be made a little more showy if possible.

ORGANISATION

The most successful shows are founded on a selection of experiments suggested by the boys themselves. Hence, about two months in advance, volunteers should be called for and each should be told to produce full accounts (with diagrams) of experiments he would like to demonstrate. This brings a number of suggestions, some utterly worthless, some crude but capable of improvement. Furthermore, it often brings acceptable offers of apparatus on loan.

The number of boys collected should be at least twice as great as the number of experiments that is likely to be shown. Two and a half hours is a usual time, which is too long to keep one boy on. A change over at half-time is necessary in order to keep the show from getting ragged at the end.

In selecting items, especially from the boys' suggestions, and in coaching the boys in their parts, the truth underlying Dr. Johnson's remark that " Men more frequently require to be *reminded* than informed " should be borne in mind.

EXPERIMENTS

The Twin Pendulum Harmonograph Experiments
Foucault's Pendulum (see Part I, p. 26).
Elasticity demonstrated by a golf ball bouncing on a thick

iron plate (see Part I, p. 23), or better, a steel ball-bearing rebounding from a thick, slightly concave glass slab.

Centre of Gravity (*C. W. Kearsey*).—Many will remember the very striking Centre of Gravity Exhibit in the Science Museum at South Kensington.

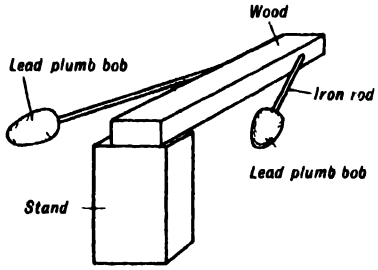


FIG. 258.

Starting with a piece of wood, 12 in. × 1¼ cm., about 1 in. thick, iron rods, about $\frac{3}{16}$ in. diameter, are screwed in. These carry lead plumb bobs. This arrangement can be set up so that the whole balances on the end of the wood block. It is advisable to start with a piece of wood that is just too long, and pare it down gradually.

Soap Films and Soap Bubbles.—For Boys' Soap Solution (see Part I, p. 35).

The Rainbow Cup.—This toy can be bought.

Surface Tension.—For a large number of suitable experiments see Part I, p. 28.

Brownian Movement is very well seen in tobacco smoke if a microscope with a sub-stage box is available. Alternative method: dissolve a little gamboge in methylated spirit and pour into water. Mount a little of the milky fluid and examine with a $\frac{1}{12}$-in. oil immersion lens.

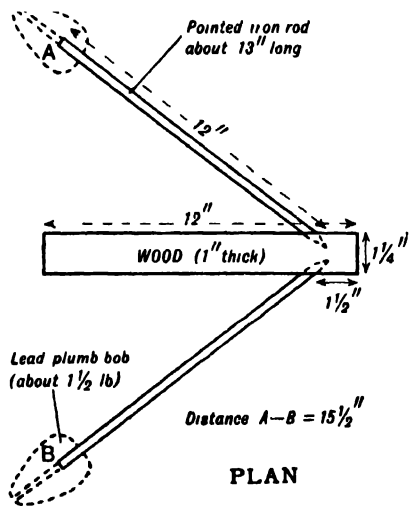


FIG. 259.

Vortex Rings in Air.—Cut a hole, 1–2 in. in diameter,

in the bottom of a box. Replace the cover by a piece of wood about 1 in. smaller than the box each way. Fasten this loosely to the sides with some strong flexible material. Give the loose back a smart blow, when an air wave will be produced which will put out a candle at a good distance away. With ammonium chloride "smoke" large vortex rings can be produced. The fumes, however, may become objectionable.

Stationary Waves, shown with string or rope fastened to an overhead beam and sloping down to a bench.

The Air Pump.—Various experiments. The Guinea and Feather experiment is well known. A common barometer set up under a tall receiver attracts a great deal of notice.

Ball and Funnel.—Connect the tail of a funnel to a water tap. Turn on the water and push a suitably sized celluloid ball into the funnel. The ball is held up, contrary to expectation.

The Ever-flowing Tap.—Suspend a brass tap from a support by a wire. Pass into the tap a glass tube of smaller bore, with its other end concealed and connected to a hidden water supply. Pass as fast a stream of water as possible up the tube. This can often be set up in a corner sink and water obtained from the next laboratory. It is sometimes set up as an ever-flowing kettle. In this case, the glass tube is bent to the shape of the stream coming from the spout of a kettle.

A Designograph can be constructed from Meccano parts and driven by a small motor. Effective designs can be produced with coloured inks.

Eggs.—A hard-boiled egg will spin on either end, but a raw egg will not. The eggs may also be placed in cotton cradles and suspended from retort stands by bifilar suspensions.

Automatic Fire Alarms.—(1) A composite zinc-copper strip with a pointer makes contact with mercury in a cup as it bends on being heated. As soon as contact is made, an electric circuit with a bell is completed and the alarm sounds.

In case the bell does not wake the people, there is a second pointer which will also make contact with a second surface. This also completes a circuit which will heat a platinum wire and fire a small quantity of gunpowder or mercury fulminate.

(2) In another type of alarm, the pointer is attached to a

weight fixed to the middle of a long piece of wire, held at both ends. The sagging of the wire on being heated causes the pointer to close a circuit and ring a bell.

The Fire Syringe.—This experiment may give some trouble. The German tinder must be well dried by placing it in a crucible for some time on hot sand.

A Thermocouple Electromagnet, now supplied by various firms.

Cloud Formation.—A flask containing a little water is illuminated and connected to a good pump. A cloud is produced by rapid exhaustion. The effect is much more striking if the pressure of the air inside the flask is increased before exhausting.

A Lycopodium Corona.—A beautiful corona is formed when lycopodium powder is dusted on to a glass plate and the source of light viewed through it.

Heat Conduction, Radiation and Absorption.—Use sensitive paper prepared with cobalt chloride (see p. 78); or, to show the different conducting power of different metals, place wires of different metals under heat-sensitive paper and heat at one end of the wires.

Demonstrate heat shadows.

Focus radiant heat rays.

Demonstrate the absorptive power of various surfaces.

A Home-made Dragoyle (C. W. Kearsey).—A "Dragoyle" or Air Tester, such as may be purchased from most of the leading opticians, looks like a grotesque green lizard, and through a glass tube connecting its mouth and its tail, passes what appears to be an endless stream of blood. The rapidity with which the red liquid passes up the tube depends on room temperature and the relative humidity of the atmosphere, and if the former is known, the latter may roughly be estimated, once the instrument has been calibrated. Apart from its scientific interest, both in the principles which underlie its working and in its application, the instrument has a certain fascination in that it appears to be an example of perpetual motion.

The instrument consists essentially of two small but unequal glass bulbs, joined by a piece of glass tubing, about 1–1½ in. long, exhausted of all air and containing a small quantity of coloured alcohol. Round the larger bulb is

wrapped a piece of absorbent cloth kept moist by contact with a small water container. The consequent cooling of this bulb and resultant drop in vapour pressure inside it are the cause of the motion of the alcohol, which is continuously driven to the upper bulb, only to fall back again on reaching it.

Fig. 260 illustrates the construction of the essential part of the Air Tester. A piece of glass tubing ($\frac{1}{8}$–$\frac{5}{16}$ in. internal

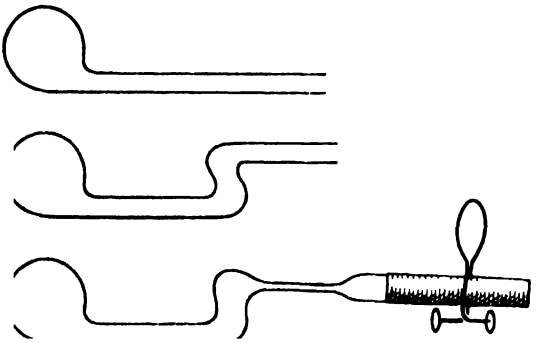


Fig. 260.

diameter), 7–9 in. long, is taken, and a bulb blown on one side by sealing the end and then allowing the end to sag approximately at right angles to the tube before blowing. The second bulb is little more than a bend in the tubing, slightly blown out while the glass is still hot after the bending. The tube is then drawn out and fitted with rubber tubing and clip, as illustrated in Fig. 260. The arrangement is now held vertically with the clip open, the larger bulb is heated, and as it cools, alcohol coloured with magenta (or any suitable dye) is poured in until the bulb is at least half full. It is then immersed in boiling water, with only the clip above water, until it is estimated that the correct amount of alcohol remains. The clip is closed, the arrangement removed from the hot water and put into cold water. If held on a slight slope, with the fingers round the smaller bulb, the alcohol should be driven *rapidly* to the upper bulb: if so, the instrument may be sealed up and should present the appearance shown in Fig. 261. It may now be mounted according



Fig. 261.

to taste and ingenuity. Fig. 262 illustrates one of the forms in which it was presented in the Members' Exhibition of the S.M.A. in January 1930. The " body " or water container

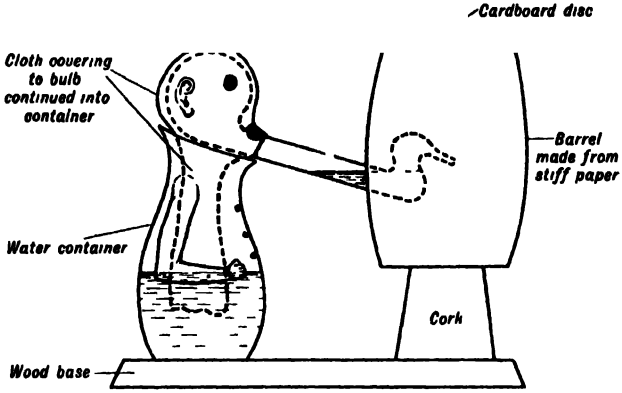


FIG. 262.

is easily made from a blown-out and cut-down test-tube, the flanged opening at the neck being made by forcing into shape with a waxed iron rod after heating the glass. The glass is then coated with Dennison's sealing-wax or coloured cellulose varnish. Different colours are used for the jacket and trousers, and if cellulose varnish is used, the tube is simply dipped in the paint. Decorations to the cloth head and to the body are done with a little sealing wax, melted on the end of a penknife or very narrow spatula. Moulding can be done with a cold penknife or knitting needle on the reheated wax; for wax work, a spirit lamp or very small Bunsen flame should be used.

The Scotsman's (or Englishman's) Dilemma (C. W. Kearsey).—Fig. 263 shows how to set up an optical illusion based on total internal reflection.

Viewed from A one sees the halfpenny.

Movement of observer from A to B results in disappearance of halfpenny and appearance of shilling in its place.

PP^1, two lantern plates or pieces of glass, are cemented together with cellulose varnish, with an air film between. Angle θ found by trial. The double glass plates are fixed to the side of the tank with plasticine.

Crookes' Radiometer.

The Cryophorus.

The Optical Smoke Box (see Part I, p. 65).

Seeing through a Brick.—Conceal two right-angled prisms in a shallow box with a bridge across to carry the brick. Arrange two other prisms on top of the concealed prisms respectively, so that at each pair of prisms a ray of light is

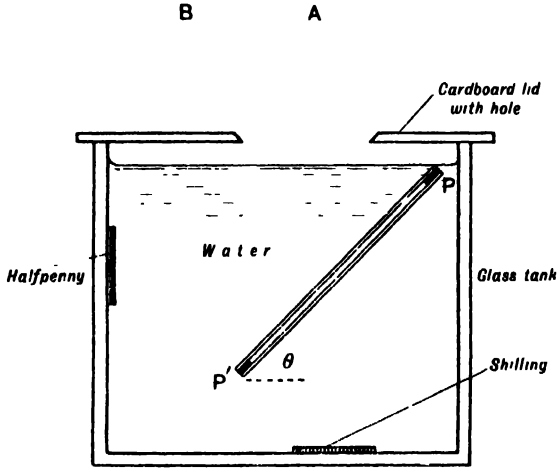


FIG. 263.

bent twice at right angles. Mount a small flash-lamp bulb as the source of light.

Real Image.—Mount an artificial flower upside down in a box, and illuminate it with an electric light shaded on one side. Produce the image with a large convex lens. Arrange three other artificial flowers in a vase of sand so that the image makes a fourth.

Produce a Caustic Curve (see Part I, p. 99).

Monochromatic Light.—Paint a box dead black inside and divide into two compartments. Illuminate one-half by a "daylight" bulb and the other with sodium light. Examine coloured objects in each compartment.

Polarised Light—Chameleon Experiment.—A is a lantern. B is a Nicol's prism, of as great an aperture as possible, fitted immediately over the end of the objective.

(A piece of brass tube, fitted with suitable lenses and with the Nicol mounted in a cork and pushed in the end, serves quite well for an objective.)

C is a sheet of stout mica at an angle to the normal as shown. Two or more sheets cemented together with Canada balsam may be advantageous. D is a convex lens of such power as to throw a patch of light on the disc, E, of sufficient size to illuminate the chameleon. This lens may be unnecessary if the objective is suitable

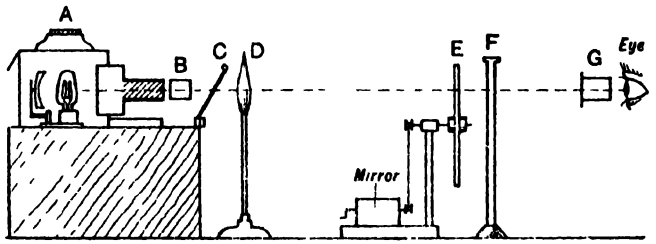


FIG. 264.

E is a glass disc, 10–12 in. in diameter, suitably mounted (e.g. on a piece of steel rod through a hole in its centre and secured with corks). This is rotated slowly, by some such means as a gramophone motor (about 30 r.p.m.). On the lantern side of the disc are cemented, with Canada balsam, small thin sheets of mica, so as to cover completely the whole area of the glass. The other side of the disc has a ground frosted surface.

F is a screen consisting of a piece of ground glass on which has been pasted a sheet of black paper. A shape representing a chameleon, about 4 in. long, is cut out of the paper. Details of the animal are drawn in pencil on the glass. The screen is as close as possible to the disc. The screen is examined by means of another Nicol, G.

Tourmaline spectacles, if available, would be more satisfactory than the second Nicol.

A circular disc is most easily made by cutting a regular polygon and grinding off the corners on a grindstone. Some glaziers will cut circular discs.

The Nicol prism must be large in order to permit of the passage of sufficient light, but large Nicols are now somewhat

expensive. Owing to the loss of light in the system at several places (ground-glass surfaces and Nicol prisms), a source of light of greater power than might be anticipated is required for a successful experiment (100-watt gas-filled lamp at least).

The Spectrum.—Produce a large spectrum, as on p. 103,

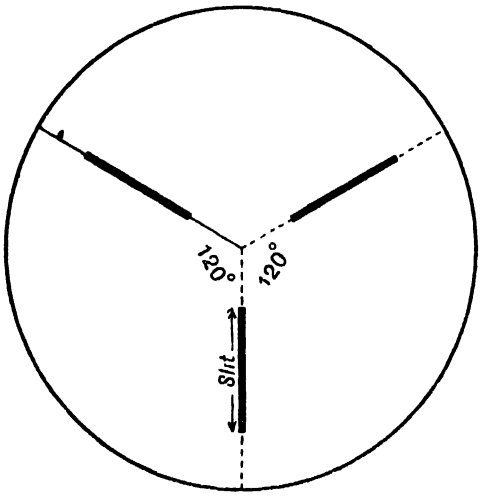


FIG. 265.

Part I. Demonstrate absorption by solutions of potassium permanganate, chlorophyll and blood.

Colour Mixing. See Part I, p. 72.

Ultra-violet Light and Fluorescence. Part I, p. 92.

Vacuum Tubes.—Join up several vacuum tubes and an induction coil with a commutator so that the tubes may be illuminated separately.

The Optical Harmonograph.—Mount a small lamp upon an arm rotating uniformly about a fixed centre. Viewed edgewise, this will appear as a straight line of light. By means of a convex lens and mirror, throw an image on to a screen. Lastly, give the mirror a vibratory motion.

The Stroboscope.—This can be set up in a more showy form than ordinarily. A lantern with the objective removed, a scanning disc and an image disc are required, together with two small motors to drive the discs. The scanning disc

(Fig. 265) is a disc of thick cardboard or thin sheet metal, painted black and having three slits cut so that each slit-pair forms an angle of 120° at the centre of the disc. The image

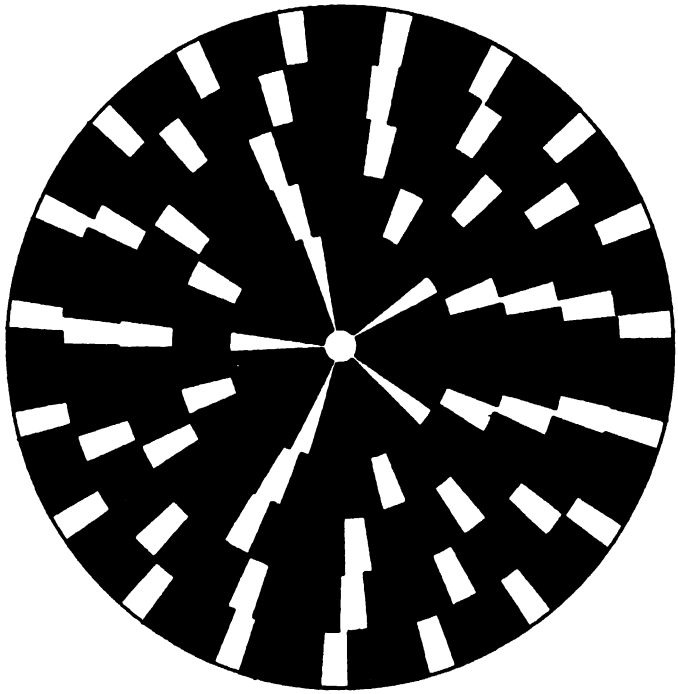


FIG. 266.

disc is painted as shown (Fig. 266), with alternate black and white segments. Even and controllable running of the scanning disc is essential. Two copper electrodes, dipping into water just tinted with copper sulphate, form a suitable resistance for varying the speed of the motor gradually.

The Photometer.

The Kaleidoscope.

Burglar and Fire Alarm (E. Bolton King).—Apparatus required:

1 photo-electric cell.

1 lantern to project beam of light.

1 valve (PM6).
1 relay. (To work on 5 milli-ampères if possible.)
2 valve-holders.
1 electric bell.
1 box for cell.
About 180 volts H.T.
Battery for bell.
Battery or mains for projector lamp.
Milli-ammeter.
Six-volt accumulator for valve; 5 Ω grid leak, grid bias battery.
50,000 ω wire-wound resistance.

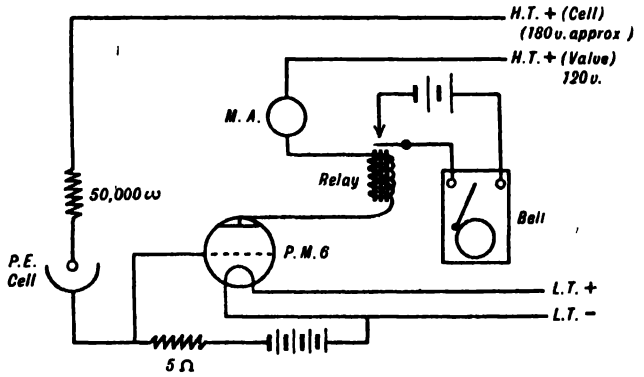


FIG. 987.

The cathode of the cell is connected to the grid of the valve.

The cell voltage should not be increased more than is necessary to get the necessary change in anode current.

The grid bias is so adjusted that when the light of the lamp is *not* on the cell, only a small current (1–2 milli-ampères) passes in the anode circuit of the valve. When the light is switched on, the anode current will increase to about 10 milli-ampères. The relay must therefore allow current to pass in the secondary only when there is very small current in the primary.

The cell should be contained in a light-tight box with a projecting tube, about 3 in. long, in front of the window, to keep out stray light.

The projector may be fitted up in any convenient manner which will shine as much light as possible on to the cell.

(A motor-car head-lamp bulb run off batteries or mains, with a resistance and a condenser lens, is very good.)

The distance at which the apparatus will work will depend on the light which reaches the cell and on the relay and cell voltage.

A good demonstration is to put the lamp and cell on different tables or on either side of a door, when the bell will ring each time a person passes between them or blows smoke into the beam. The beam will not be very noticeable in a well-lighted room.

Luminous Cascade.—Fit a half Winchester quart bottle with an inlet and outlet tube for water. Paint the bottle outside with black paint, leaving only a small clear space in the bottom of the bottle for illumination. Set up in a dark corner.

Short Sound Waves.—Very pure sounds of exceedingly short wave-length are produced by joining up a thermionic valve with a condenser and an inductance.

Show that these short sound waves can be reflected by a large mirror and brought to a focus. Use a sensitive flame to detect the sounds.

Bring the waves to a focus by means of a large balloon filled with carbon dioxide.

Arrange two similar sources of sound to produce interference.

Locate the stationary points by a sensitive flame.

By decreasing the capacity of the condenser, raise the pitch of the note until it just becomes inaudible. Calculate the number of vibrations per second from the setting of the condenser.

Melde's Experiment (see Part I, p. 129).

An Electric Bell in a Vacuum.

Chladni's Plates.

Singing Tubes.

Reflection by large concave reflectors.

Radio Rex is a very amusing toy. Unfortunately it has been difficult to obtain in recent years.

Gramophone Record.—Project the wave form of a gramophone record while the instrument is playing (see Part I, p. 131).

Floating Magnets.—A number of small magnets are equally magnetised and provided with small floats so that they will

just float with their north poles upwards. Bring a strong south pole over the centre of the tank and float the small magnets in the water one by one.

Experiments with an Electromagnet.—Show magnetic induction and that magnetic force acts through most substances, but iron is a more or less effective screen. Produce a magnetic chain.

The Floating Bottle.—Mount an electromagnet as shown in the figure. Twist a piece of copper wire round the neck of a small bottle, having previously made three small loops in the wire before it is fastened to the bottle. To these loops attach strings fastened at the other end to a piece of wood. In the bottom of the bottle put a few iron nails concealed by cotton wool.

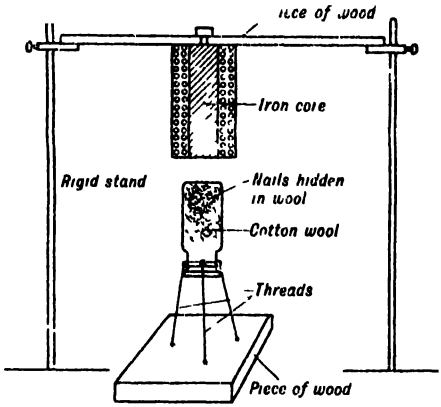


FIG. 268.

Cobalt-steel Magnets.

Production and Detection of Hertzian Waves.—Fig. 269

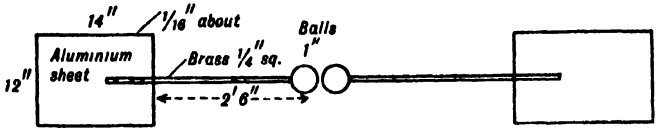


FIG. 269.

shows a suitable pattern for a transmitter and receiver. This is mounted on a strip of board with a 3-in. hole in the middle, so as to give room for the balls.

Fig. 270 is another, and, in many respects, a more convenient form. Mechanism for adjusting the air gap, as shown in Fig. 271, is desirable.

The Katharometer consists essentially of four coils, two of manganin and two of a pure metal (preferably platinum, but

any pure metal will do). These four coils form a Wheatstone bridge, and on passing a current through the bridge in the usual way, the manganin coils will remain practically constant in resistance, while the platinum coils will change in resistance owing to the rise of temperature that takes place.

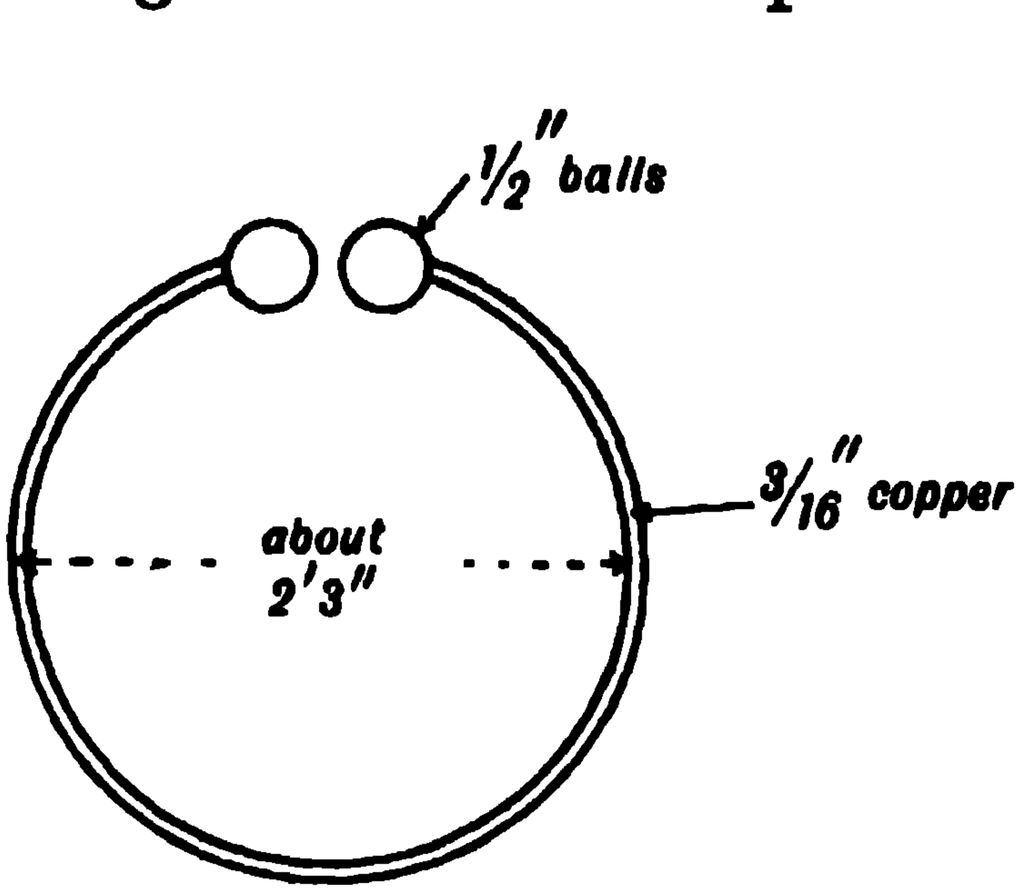


FIG. 270.

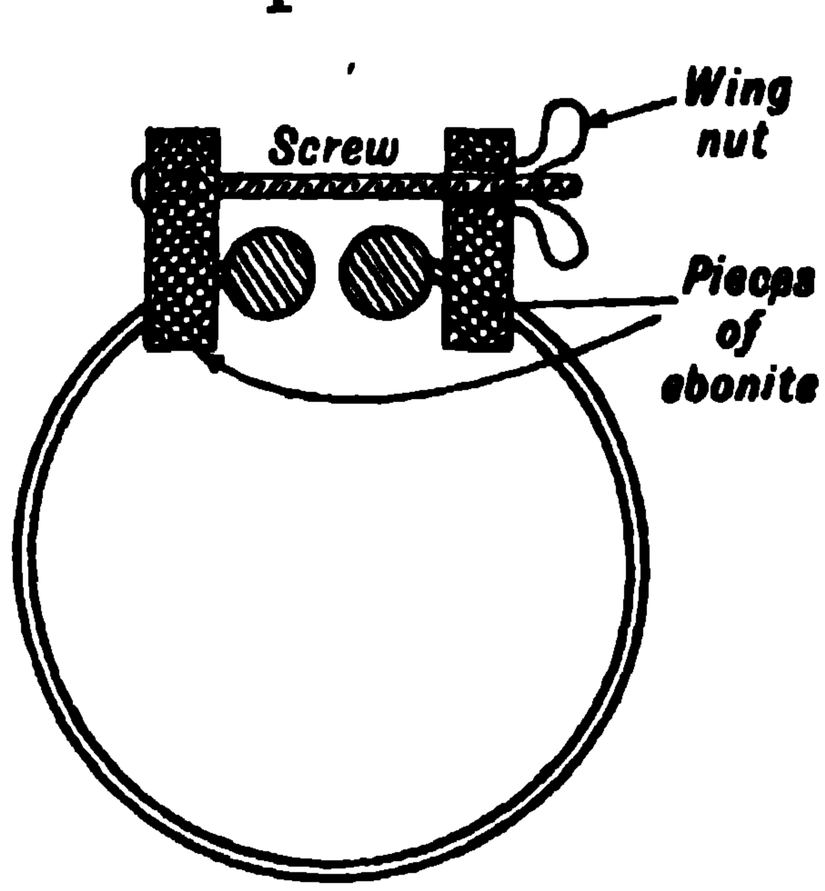


FIG. 271.

Fig. 272 shows one coil of No. 47 wire made into a small spiral by winding on a knitting needle with a lathe. The spiral is mounted on a piece of ebonite rod, about $\frac{3}{8}$ in. diameter, of which part has been filed away as shown in the figure. A small hole is drilled in one end of the rod, as shown, to allow diffusion to take place into the space around the coil. Brass

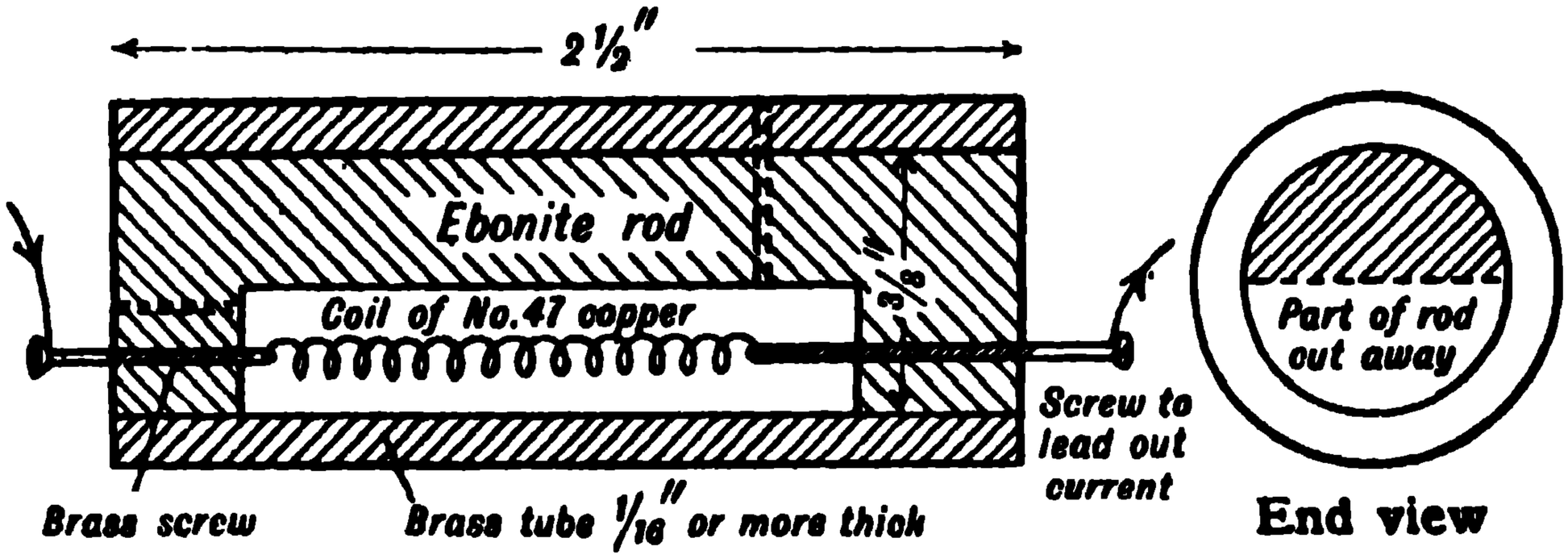


FIG. 272.

screws are used as leads to the coil. The ebony rod is generally slipped into a piece of thick-walled brass tubing or into a piece of rod with a $\frac{3}{8}$-in. hole. The thicker the brass the better, but $\frac{1}{16}$ in. will do. An article on the katharometer appears in *S.S.R.*, Vol. XII (47), March 1922.

If, however, the air round one of the platinum coils is displaced by another gas, a change in temperature will occur

because of the difference of heat conductivity of the gas causing a greater or less loss of heat, accompanied by a change of resistance. Thus the balance of the bridge is disturbed and the galvanometer shows a deflection proportional to it. The most minute quantity of hydrogen, ·001 c.c. in 1,000 c.c. of air, is capable of detection by this method.

Many applications of the katharometer are possible, such as the detection of fire damp in coal mines, the finding of leaky points in a gas balloon or airship, or the finding of the amount of carbon dioxide produced during respiration by a fly.

Simple Cell made from a Lemon.—Use a knife and fork as electrodes.

Wimshurst Machine.—Illustrate discharges.

Mercury Vapour Lamp.

Diffusion.

Silvering Glass (see p. 80).

Etching Glass.

Rupert's Drops.—These can be bought. Nip off the ends with gas pliers under a large beaker.

Silica.—Heat silica rod to redness and plunge into cold water. Show the properties of silica by heating a silica flask directly with a large blowpipe flame. Show quartz crystals and silica fibres.

Electric Writing.—Soak filter paper with sodium chloride solution containing a little phenol phthalein. Place the moist filter paper on a sheet of metal and write with a wire cathode.

Vary by using potassium iodide and starch solution as the electrolyte.

Crystals.—Prepare and mount crystals (see p. 12).

Grow some crystals of alums.

Crystals of Silver, Lead and Tin. Lead Tree.

Liquefaction of a Gas by Pressure.—Enclose sulphur dioxide in a tube with a capillary end. Connect to a mercury reservoir by pressure tubing.

Condense Water from a Bunsen Burner.

Pass Steam over Red-hot Iron and obtain Hydrogen.

Demonstrate Recalescence of Iron (see p. 1).

Liquid Air.—A liquid-air demonstration is always popular. Three to four litres will be required. The liquid air can be bought the day before without appreciable loss. Fit the flasks with an aspirator fitting and drive out the liquid by

blowing with foot bellows. This is better than pouring it out. Hire a vacuum beaker.

Glass Blowing is of perennial interest, particularly if a little exhibition work can be attempted. For example: the principle of the steam turbine can be illustrated by making a thin glass bulb (1–2 in. diameter) with a concave bottom and a drawn-out neck with a fine jet. The bulb is half filled with water and the end of the neck bent through a right angle. The bulb is made to rest on one end of a copper wire, the other end of which is wound loosely round the neck. The copper wire also serves as a handle to hold the bulb. On boiling the water, the jet of steam causes the bulb to rotate at great speed.

Colloids.

Artificial-silk Demonstration.—To a saturated solution of copper sulphate add ·880 ammonia until the deep blue liquid is obtained. Dissolve filter papers in this liquid to make a fairly stiff jelly. Draw out some 1-in. tubing (6 × 1 in. test-tubes are convenient) to make jets. These should not be too fine. Charge the jelly into the tubes and attach these to the blower described in Part I, p. 245. Immerse the jet in 50 per cent. sulphuric acid and draw out the thread very carefully with crucible tongs. Wind on a boiling tube rotated by a gramophone motor. The speed of the motor is easily regulated. If the product is washed on the boiling tubes, a pale blue product is obtained, which can be unwound and festooned loosely across a row of burette stands.

Silicate Growths — Aquarium sand is put into a large glass vessel and sodium silicate (1 lb. of water glass to about a pint and a half of water) added. Crystals of ferrous sulphate-copper sulphate and nickel sulphate are first put in and allowed to sprout well Crystals of aluminium sulphate, cobalt nitrate (or chloride) and ferric chloride crystals are added later.

Chemi-luminescence (see p. 7).

Burn Air in Coal Gas.

Vortex Rings of Incandescent Carbon.—Cover the chimney of an upright Argand with fine wire gauze, light the burner and turn it down to a mere flicker. Deliver coal gas through a fine blowpipe jet in contact with the wire gauze. A vortex of incandescent carbon particles will be formed about half-way down the chimney.

Indicators.—The experiment on p. 65, if nicely set up in

small beaker flasks, is very attractive, especially in artificial light. Some applications of indicators should be demonstrated at the same time.

Volumetric Analysis.—A titration of alkali with acid, using phenol phthalein or thymol phthalein or an iodine-thiosulphate titration, is a pretty experiment.

Minerals.—A selection of about twenty striking minerals is sure to interest, especially if accompanied by simple mineralogical tests.

Foam Method of Extinguishing Fires.—This is interesting but rather messy.

Soap Bubble Floating in Carbon Dioxide.—For this, one or two large bell-jars, really shades, are required. The carbon dioxide must be washed. If the extinction of flaring brown paper is also shown, the smoke particles become entangled in the heavy gas and the level of the carbon dioxide can be seen. A cover of thin cardboard is required to break the draughts.

Vortex Rings in a Liquid.

The Properties of Wire Gauze and the Safety Lamp.

Liesegang's Rings.

Transition Points (see p. 94).

Electro-plating.

Steam Distillation.—Phenyl butyrate is suitable and has a faint, pleasant smell.

Perfumes.—Fill as many glass jars as are required with cotton wool. Add one or two drops of the essential oil to each.

Mercury.—A dish of mercury with various objects floating in it may be shown if a sufficient quantity of mercury is obtainable.

Experiments on Plants.—Germination, transpiration, carbon assimilation.

Respiration of Plants, using the continuous gas method and indicator methods.

Irritability.

Rate of Growth of Plant Stems (see p. 202).

Spores of Equisetum.—Show behaviour of the extremely hygroscopic elaters. The spores, if collected in spring and stored in a dry glass tube, retain their power for years.

Collections of Local Flora.

Collections of Fungi.

Plant Diseases (see p. 207).

Plant Nutrition.

Living Aquatic Algæ and Protozoa, especially *Paramecia.* Movements of chloroplasts in *Elodea.*

Yeast and starch granules are always popular microscope objects.

Working Models of Flowers whose Mode of Pollination is Ingenious.

Exhibition of Models.—Mosquito, Housefly, etc.

Microprojector.—Life-histories of mosquito, jelly fish.

Physiological Models.—Brain, ear, eye, etc.

Collections of eggs, moths, etc.

Colour Changes in Animals.—Frogs, chameleons, Æsop prawns, Sepiola.

Examination of Own Blood Corpuscles.

Heart Beat of Frog.

Circulation of Blood in frog's foot, or in tadpole.

Vivaria.

Aquaria.—Fresh-water and marine.

Physiological Experiments, illustrating measurement of blood pressure, graphical record of pulse.

Experiments in Bacteriology.—Growth of bacteria on various media.

Mycodermum Aceti.

Lactic acid bacillus.

Numbers of bacteria in baked and unbaked soil.

Preservation of food.

Solid Matter in Air.—Expose a plate of sterilised gelatine to the open air for two minutes; afterwards place in an incubator.

Development of the Chick.—Incubate hens' eggs for 2, 3, 5 and 7 days respectively. Remove the shell in 0·75 per cent. salt solution at 40° C. and examine the embryos.

APPENDIX II

FIRST-AID IN THE LABORATORY

A. St. G. Huggett, M.D.

THE accidents of the laboratory fall into two classes, avoidable and otherwise. We here deal with those which have not been prevented, and so can omit questions of prophylaxis.

In all cases of serious accident, or where there is any doubt as to the gravity or otherwise of the case, send for the school medical officer, advising him at the time, for the patient's sake, of the nature of the accident, how it was caused and the part of the body injured or burnt.

Burns.—The slightest burn is painful. Consequently, pain is the first thing which calls for treatment. A boy with stamina will stand a slight burn with ease, and probably will not be much the worse; if without stamina, he may make a noise out of all proportion to the cause. Fortunately, again applying the law of averages to the average British boy, his upbringing and his codes forbid a fuss. At the same time, in the case of an extensive burn (rare in the laboratory), even if no fuss is made, it may be wise to get a medical opinion in the case of shock or collapse supervening, a danger rather apt to occur with large painful burning of the skin. In connection with this, it should be borne in mind that a mild burn over an extensive area is much more serious than a severe burn at a small point. The important thing is to relieve the pain and consequent liability to shock, and to prevent sepsis. The best way to do this is to immerse the burnt area in oil immediately. Olive oil or vaseline will do quite well. The time-honoured medical oil for the purpose is carron oil, which is slaked lime mixed with linseed oil, and is an excellent analgesic. Picric acid, 1 per cent in water, is excellent for small burns. It coagulates the proteins and so paralyses sensation, and still more is antiseptic. But it must not be used for extensive burns on account of the danger of

absorption from big areas, causing poisoning. Whatever dressing is used, put a covering of lint on the surface to protect from the air.

Burns are frequently followed by blisters, which are best treated by washing with ether and pricking the skin with a needle (not cutting the skin away), sterilised by passing through a flame and cooling under a tap. Running water from all modern British water-works is practically free of pathogenic organisms. In the case of burns accompanied by the impaction of hot or caustic metal (sodium, etc.) in the skin, remove the particle with tweezers, forceps or needle, wash in *water*, and then treat with oil.

Acids, Alkalis, Bromine and Dyes.—The effects of acids and alkalis on the skin are best treated by washing thoroughly with water. Do not neutralise a strong acid with strong alkali, but if a strong alkali has caused the trouble, it is worth while washing with 1 per cent acetic acid, which removes both the soapy feeling and the alkali. A bromine burn can be best treated by washing with normal sodium hydroxide. A useful dressing on any raw surface produced by acids, alkalis or burns, which can be left on for several days unchanged with gauze, wool and bandage, is a lotion of 1 gram of alum (pure)—potash or ammonia alum being equally good—0·5 gram of zinc sulphate crystals, 200 c c. of glycerine and water to 500 c.c. It is antiseptic, soothing and non-poisonous as an external application.

Staining with dyes is usually best left alone, though the chemical antidote can be tried, provided it is not drastic. In many cases, soap and water and a scrubbing brush satisfy the æsthetic taste. Alternately, methylated spirit and 50 per cent. alcohol are good solvents, especially for biological stains such as eosin or hæmatoxylin.

Eye Accidents.—Accidents to the eyes, if serious, ought to be seen by a doctor. A small foreign body in the eye can be removed by opening the eye wide under water, or everting the eyelid on a match and looking under it. Remove the particle directly with a moist corner of a handkerchief or a spud of moist wool. Wash in water and let it cure itself.

Bromine in the eye is most suitably dealt with by immediate washing with 1 per cent. sodium bicarbonate solution, and then with water in large quantity. This does not,

however, dispense with the need for a doctor, who should always be consulted in regard to ophthalmic trouble on account of the physiological importance of the affected organ.

Wounds.—A type of accident often met with in laboratories is cutting or laceration in one form or another. In this the golden principles are to stop the hæmorrhage and remove any dirt, glass or other foreign substance which has become implanted. Hæmorrhage falls into three classes surgically—arterial, venous and capillary ; but for most first-aid purposes there are only two kinds of bleeding—one arterial, where the blood spurts intermittently and is bright red, the other where it flows steadily and is darker.

Arterial hæmorrhage must be stopped at once. To do this in a limb a tourniquet must be applied. The simplest is a turn of rubber tubing round the arm or leg, or in the case of a finger, round the whole finger at the base. This compresses the artery above the bleeding point against the bone. Twist the tubing up against the arm until the hæmorrhage stops, then tie a clamp. A handkerchief with a pad over the main artery will act quite well, but requires more skill in applying. In any case, no tourniquet should be left on for more than half an hour. It is only for an emergency. Take the patient, with an antiseptic dressing over the wound, straight to the doctor. If the tourniquet is left on for more than 30 minutes, there is a danger of gangrene due to stopping of the circulation. It also causes unnecessary pain after a time.

With capillary hæmorrhage, where there is no spurting of bright red blood, procedure can be more leisurely. If any obvious glass or foreign body is present, pick it out with tweezers which have been sterilised in a flame and water, or in alcohol. Then sponge with cotton wool and pour on antiseptic fluid. The time-honoured fluid is tincture of iodine, which is a 2·5 per cent. solution in 75 per cent. alcohol and containing 2·5 per cent. of potassium iodide. Any solution of iodine will do in an emergency. It has two virtues : it is highly antiseptic, and it tends to stop hæmorrhage by precipitating proteins from the blood. It is, however, very painful, and consequently some doctors use ether with equal efficiency. Ether is always available in any science laboratory in an emergency. It is, of course, unnecessary to mention

the inflammatory properties of ether, and particularly how the ether vapour runs along the bench to a Bunsen some distance off. The tendency of ether to explode horizontally rather than upwards is well known.

Poisoning by Fluids.—Under this heading we can include that common type of accident in which a boy sucks fluid of one type or another into the mouth, without necessarily swallowing it. Here, of course, prevention is better than cure, and the first rule ought to be that strong acids and alkalis ought never to be sucked up in pipettes; secondly, no pipette should be used in which the mark is too near the mouth and invisible when being used. With the experienced chemist this will not matter, but it is of importance with the inexperienced boy. Now, as boys will be boys, both these precautions will be ignored and fluid will get into the mouth. There are then only two things to do: spit it out at once, and wash with water again and again. Do not, unless you want to increase the pain later, neutralise chemically. Water in large quantities is the only effective treatment.

Should the accidental mouthful of fluid be swallowed, then it is usually best to drink large quantities of water, and dilute it. If acid has been swallowed, let the water be lime water, but if alkali, add vinegar to the water or use 1 per cent. acetic acid. Salts of heavy metals, such as mercury or lead, are best treated by swallowing white of egg, and, in lieu of this, milk. The proteins fix the metals and prevent absorption. Emetics and purgatives should not be given with strong acids and alkalis; they may rupture the corroded stomach. Irritant poisons, such as arsenic or mercury salts, cause vomiting; promote this by further emetics, notably mustard (1 teaspoonful in a tumbler of water), or common salt (1 tablespoonful in a tumbler of water). Cyanides, if swallowed in quantity, are the most deadly type of poison, and the only thing to do is to give artificial respiration, send for the doctor and hope for the best, combining oxygen inhalations with the respirations. The artificial respiration is best carried out by putting the patient on his stomach, sitting on his buttocks, with both hands compressing the sides and back of his chest against the floor, and then lifting one's weight off. In this way the chest is compressed and relaxed. Repeat the movement twenty times a minute.

Gas Poisoning.—The commonest gases are coal gas, carbon

monoxide, carbon dioxide, chlorine, sulphur dioxide and hydrogen. Of these, chlorine and sulphur dioxide are acute pulmonary irritants, if inhaled in quantities. Such was their use in France. They are, however, so pungent (and in the case of chlorine there is the colour) that they are never inhaled to the dangerous degree. The same applies to coal gas —its smell is protective. But the chief danger of coal gas is in its carbon monoxide content, and this is the most dangerous gas of all. First, it has no smell; secondly, the first sign of poisoning is the collapse of the patient. He will be panting and red in the face. The hæmoglobin of the blood has an affinity for carbon monoxide which is three hundred times its affinity for oxygen. Consequently, carbon monoxide deprives the blood of its oxygen-carrying power, and causes death by asphyxia. So the first thing to do is to remove the boy from the impure atmosphere to pure atmospheric air; the second thing is to keep him breathing and gradually to displace the carbon monoxide by oxygen. This object is best attained by holding the delivery tube of a carbon dioxide Kipp apparatus (or a carbon dioxide cylinder) about 1 in. from his nose. He will thus be given the normal stimulus to respiratory movements in an increased degree, and so will dilate his chest and take in the extra oxygen required to displace the monoxide from the blood. Artificial respiration may be required, but this is improbable unless he is moribund from the long immersion in the carbon-monoxide-laden atmosphere. In any case, send for the doctor right away. If moribund, it may be necessary to perform transfusion of blood. Fortunately, the patient will pick up from the time he is removed, provided he has not become too saturated with the toxic gas. In that case, blood transfusion is the only resource.

With hydrogen there is no danger except in so far as it displaces the oxygen of the atmosphere. It is insoluble in blood and non-toxic. Carbon dioxide rarely reaches a pathological concentration. This is at 8 per cent., when it causes respiration to cease. It is almost impossible to achieve this concentration with a Kipp delivery tube applied 1 in. from the uncovered nostrils, as recommended for carbon monoxide poisoning.

Fainting.—Should fainting occur as a result of these casualties, either in the boy or an onlooker, the first thing to do is to lower the head and promote a good flow of blood thereto.

This will often prevent fainting before onset. Next loosen the boy's collar, and hold ammonium carbonate under the nose so that it is inhaled. Ammonia acts as a most excellent cardiac stimulant and counter-irritant to the mucosa of the nose. On recovering, a teaspoonful of brandy in a teaspoonful of water (or one teaspoonful of absolute alcohol in two teaspoonfuls of water) will act as an excellent "pick-me-up." Where collapse occurs from any cause whatever, it is wise to give brandy and administer oxygen, stimulants being indicated. For those who feel that brandy will cause trouble on prohibition grounds, an excellent mixture to be kept in stock is 1 part ether, 2 parts absolute alcohol, 3 parts sal volatile, and 42 parts water. It tastes vile, but it does do good, and the patient always recovers rather than take any more. The dose is two tablespoonfuls (about 30 c.c.).

Finally, one must emphasise the wisdom of advising the boy to see a doctor or calling the school medical officer; since, in the event of relapse, or fatality traceable to the accident, there arises the question of responsibility, bound up with which are the legal points of the master's responsibility and possibly even manslaughter, if negligence is proved.

Danger in Handling Hydrofluoric Acid

Irvine Masson

A chemist's fingers and thumbs grow fairly callous even to concentrated reagents, especially as he does not usually allow the contact to be long; but he should be particularly careful to take no liberties with hydrofluoric acid. This, because of its common use for etching glass or porcelain, is more likely than most chemicals are to wet his skin for any length of time; and so it was in my case. The solution is absorbed by the skin and, I think, the vapour gets under the finger-nails; nothing happens for about an hour except a "crinkled" feeling; but in the ensuing hours, day and week, the nails are pressed up from below by blisters, the tissues of the fingers are deeply eaten away layer by layer, with poisonous-looking spots in the wound; one gets no sleep and the pain is very troublesome. With me, the ends of six digits were affected in varying degrees, and to my surprise and disgust the general

result was: bed for some days and one and a half useless hands for a much longer time.

Hanging the hands in changes of cold water was at first a palliative; the application of picric acid solution with cotton dressings afterwards did good; but as this kind of accident is entirely preventible, the question of remedies is less necessary than a warning of the risk.

APPENDIX III

DUTY-FREE SPIRIT

The following information may be of value to those members who have a permit to obtain industrial methylated spirit. The ordinary I.M.S. supplied is prepared by mixing 95 parts spirit with 5 parts wood spirit, and contains therefore acetone and water, as well as methyl alcohol. This I.M.S. may be obtained from the methylators without water at 4*d*. per gallon over the price of the ordinary I.M.S., and is described as "Dehydrated (74 overproof) Methylated Spirits."

The Methylating Company have also put on the market an I.M.S. denatured with synthetic methyl alcohol instead of wood spirits. The advantage of this is that it has no acetone, though the absence of acetone is not specifically guaranteed by the makers. This I.M.S. can be obtained at the same price as the ordinary I.M.S., and should be specified as "I.M.S. with synthetic denaturant."

The same company will also supply synthetic methyl alcohol in 5-gallon drums, at about 3*s*. 6*d*. per gallon. Inquiries and orders for dehydrated I.M.S., I.M.S. with synthetic denaturant, and synthetic methyl alcohol should be addressed in the first place to The Methylating Company, Ltd., Chancellor's Lane, Hammersmith, W.

INSTRUCTIONS RELATING TO DUTY-FREE SPIRIT, 70267/1922

(*a*) *Industrial Methylated Spirits, and*
(*b*) *Duty-free Pure Alcohol for use in Schools.* (*Deputation from Science Masters' Association to Commissioners of Customs and Excise, March* 1922.)

I. Particulars to be given in Applications for Authority to receive Industrial Methylated Spirits and/or Duty-free Pure Alcohol.

(*a*) *Particulars common to Industrial Methylated Spirits and to Duty-free Pure Alcohol*

1. Applications, which may be in the form of an ordinary letter, may be signed by the Head Master, a Science Master, or by the Secretary (or corresponding officer) of the school. They should be addressed to the Secretary, Custom House, London, E.C.3.

2. The name and address of the school should be given, together with an indication of the laboratories or other places where it is proposed that the Industrial Methylated Spirits and/or alcohol shall be kept and used.

3. It should be stated whether it is intended (1) to purify the Industrial Methylated Spirits received (if so, a brief outline of the purification process should be submitted); or (2) to recover any Industrial Methylated Spirits and/or alcohol by distillation.

4. The application should contain a formal undertaking that (*a*) the Industrial Methylated Spirits and/or alcohol received, and (*b*) any Industrial Methylated Spirits purified and/or alcohol recovered, will be kept (in the place or places indicated in accordance with paragraph (2)) under lock, under the control of a Master, will only be withdrawn and used under the control of a Master, and will not be used for any purpose whatsoever except those specifically mentioned in the application.

(*b*) *Particulars Special to Industrial Methylated Spirits*

5. The application should state the purposes for which the Industrial Methylated Spirits are required ("science teaching" will be accepted as an appropriate description where Industrial Methylated Spirits are required for general teaching purposes on the school premises) and the quantity which it is desired to have authority to receive annually. (*Note.*—Certain special conditions may be applied if the annual quantity exceeds 50 gallons.)

(*c*) *Particulars Special to Duty-free Pure Alcohol*

6. The application should describe in detail the particular work for which it is sought to receive pure alcohol, on the ground that Industrial Methylated Spirits would be unsuitable

or detrimental. The reasons for which it is claimed that this ground exists should be clearly set out, as it is legally essential that it should be satisfactorily established in every case that Industrial Methylated Spirits would interfere with the processes contemplated. The quantity of pure alcohol required annually for the work for which it is claimed should be stated.

II. PROCEDURE

7. *Grant of Authority.*—The grant of authority will be conveyed by letter from the Secretary, Custom House.

8. *Requisitions and Permits.*—The local Surveyor of Customs and Excise will be instructed to supply the school with a "requisition" (or if appropriate, a book of "requisitions"), which, when duly filled up, should be sent to the supplier (methylator or bonded-warehouse keeper) as his authority for the delivery of the Industrial Methylated Spirits or duty-free alcohol from his premises. The "permit," which will be received with the goods on their arrival at the school, should be forwarded as soon as possible to the local *Officer of Customs and Excise* with a statement as to whether the package was received intact. If the package was *not* received intact, it should be held, in the condition in which it was received, for inspection by the officer, who will visit the school for that purpose.

9. With regard to *Industrial Methylated Spirits*, it will be a condition that a return (in an official form, which will be supplied by the local officer) shall be made, once a year, showing the quantity of spirits which have been *used for teaching* during the year. This is for statistical purposes.

CUSTOM HOUSE,
LONDON, E.C.3.
April 1922.

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